POSTATTACK RECOVERY MANAGEMENT: CONCEPTS AND TECHNIQUES FOR MODEL DEVELOPMENT

CONTRACT NO. OCD-PS-66-11
OCD WORK UNIT NO. 3531A

STANFORD RESEARCH INSTITUTE

MENLO PARK, CALIFORNIA

*SRI

STANFORD RESEARCH INSTITUTE

March 1967

POSTATTACK RECOVERY MANAGEMENT: CONCEPTS AND TECHNIQUES FOR MODEL DEVELOPMENT

By: DONALD E. CLARK, JR., AND CARL F. MILLER

SRI Project No. MU-5710

CONTRACT NO. OCD-PS-66-11
OCD WORK UNIT NO. 3531A

Prepared for:

OFFICE OF CIVIL DEFENSE
DEPARTMENT OF THE ARMY
WASHINGTON, D.C.

ACKNOWLEDGMENTS

The authors wish to acknowledge the contributions to this study made by Hong Lee, W. Leigh Owen, and Stephen L. Brown of the Radiological and Resource Systems Development program of Stanford Research Institute.

CONTENTS

CONTENTS

ILLUSTRATIONS

TABLES

INTRODUCTION

Organized postattack recovery operations can be considered in terms of sequential actions for the restoration of at least minimum operating capabilities of socioeconomic systems needed to ensure continued existence of survivors. The minimum requirements for a scheduled recovery of the systems, in terms of time, type, and amount, will depend on both the subsistence needs of individuals and the number of survivors (injured as well as uninjured). On a national basis, the expenditure of effort and supplies in recovery operations includes consideration of recovery of all systems that contribute directly or indirectly to recovery at the consumer level. The specification of organized postattack recovery operations and their management require information that relates survival needs to system recovery and operation.

At least two steps are entailed in the recovery of the output of a component of an industrial system (i.e., the physical resources of an economic system). The first is the recovery of the use of the components, and the second is the recovery of its productive operations. The actions for each step and their occurrence will depend critically on the postattack environment in a given geographical area. For areas in which the component is undamaged and received only light deposits of fallout, the first step would not be required, and the achievement of the second step would generally depend only on the availability of inputs (or acceptable substitute inputs) to the component. For areas that are exposed to high levels of blast and thermal effects in which the component is destroyed, both recovery steps are infeasible (at least within the time scale of recovery operations concerned with subsistence needs of survivors following a nuclear attack). In all other geographic areas, both recovery steps would be required, and it is in these areas that the major postattack recovery operations would take place. The postattack environments in this third category of areas would range from those in which moderate levels of fallout occurred (with no physical damage to industrial components from other explosion phenomena) to those in which moderate to heavy levels of physical damage of industrial components occurred.

Although the upper limit of damage for possible recovery of an area might be considered to occur where industrial components are damaged but reparable, the feasible limits for recovery would depend on whether the

subsistence survivor needs (including recovery of their production) could be supplied without interruption on the basis of the capabilities of the survivors (with or without assistance from nearby areas) and the resources available to them.

To establish approximate limits of feasibility for the recovery of industrial components and systems and, for those feasible, to establish requirements (with respect to survivor needs) and planning guidance (with respect to the sequence of recovery operations), quantitative estimates of the recovery process are needed. First, such estimates should provide information on the nature and scope of the recovery problem, including the specification of factors that significantly influence the limits of feasibility mentioned above. Second, the estimates should provide information on potential rates of recovery of production for survival as well as information on how the rates may depend on preattack preparations and the application of postattack countermeasures.

Since there is no experience on recovery from massive nuclear attack, system models offer a means of investigating recovery processes for hypothetical postattack situations. Exercising such models for a range of postattack situations should provide information that can be used in preattack development of effective postattack recovery planning procedures and management decision guidance criteria. Both would be difficult to develop extemporaneously after an attack.

Within the scope of this discussion, the objectives of the research in defining postattack recovery activities were:

1. To develop general concepts of models providing methods for controlling and managing postattack recovery operations
2. To describe specific approaches applicable to the development of postattack situation models
3. To indicate the scope and detail required for the development of certain models closely related to Office of Civil Defense responsibility

The approach used to achieve the objectives was to describe a postattack recovery model system, its scope, and the interrelationships of its submodels. The scope of submodels within the system was defined to ensure that each submodel, developed in detail from future related research effort, will function properly as part of the recovery model system.

The current status of each model of the system is indicated in this report, and its important input and output parameters are described. Typical model development techniques are illustrated by examples. A

relationship between model outputs and management decision guidance criteria for countermeasures of primary interest to OCD are established within the current framework of model development.

RECOVERY MODEL SYSTEM

A recovery model system consists of four types of models defining a postattack situation and the processes of recovery: weapon effects, economic systems, countermeasures, and civil defense organization to implement countermeasures. A series of submodels for each of the four functional categories of the recovery model system is listed in Table 1, together with estimates of their respective current state of development based on the existing knowledge of the required inputs and the current model capabilities. In some cases, reliable inputs are not available, no model exists, and a poor rating is given. A fair rating indicates either reliable inputs and no model or reliable inputs with some subsequent model development. A good rating is reserved for fully developed models based on reliable inputs, with expected minor improvements in the future. The references listed are neither exhaustive nor exclusive and are intended as a point of departure for seeking information on specific recovery model inputs, outputs, and parameters. In the following paragraphs, the models of the recovery system will be defined and discussed, and relationships between some of the submodel components will be indicated. Functional relationships among the four model types are shown in Figure 1.

Weapon Effects and Vulnerability Models

To define the nature and magnitude of the postattack recovery problem and to evaluate the relative cost and effectiveness of alternative postattack recovery countermeasures (or systems of countermeasures), the model system must be designed to make estimates of the degree of damage to all elements of the system. The response of the physical parts of the system and the operational parts of the system must be considered. Actually, three submodels and their associated data bases are required:

1. Vulnerability of components (response of physical parts of the system to weapon effects and the geographic location of these parts)
2. Vulnerability of operations (loss of key personnel, delay due to radiation exposure of personnel, delay due to bottlenecks, etc.)
3. Variation in basic vulnerability of components and operations

Table 1

RECOVERY MODEL SYSTEM

	Model Development Good	Fair	Poor	Typical References
Weapon effects and vulnerability models				
Physical effects				
Air blast	X			1
Ground shock	X			1
Thermal radiation	X			1
Radiological effects				
Radionuclide production	X			2,3,4
Radionuclide condensation	X			2,3,4
Fallout particle formation		X		2,3
Cloud and fallout distribution		X		2,3
Foliar contamination		X		2,3,5,6
Absorbed dose		X		2,7
Beta-gamma dose - plants			X	8
Plant root uptake		X		5,9
Vulnerability				
Physical damage		X		10
Radiation exposure		X		10
Variation with preattack countermeasures			X	10
Economic system models				
Agricultural production		X		11
Mineral production			X	12
Industrial processing			X	12,13
Transportation		X		14,15
Storage and distribution			X	14,15
Utility and energy source		X		14,15
Countermeasure models				
Postattack				
Decontamination and dose control		X		3,16,17
Debris clearance and salvage			X	18
Damage repair			X	19
Medical treatment			X	20
Evacuation		X		21
Preattack				
Stockpiling			X	22
Hardening			X	10
Dispersal			X	23

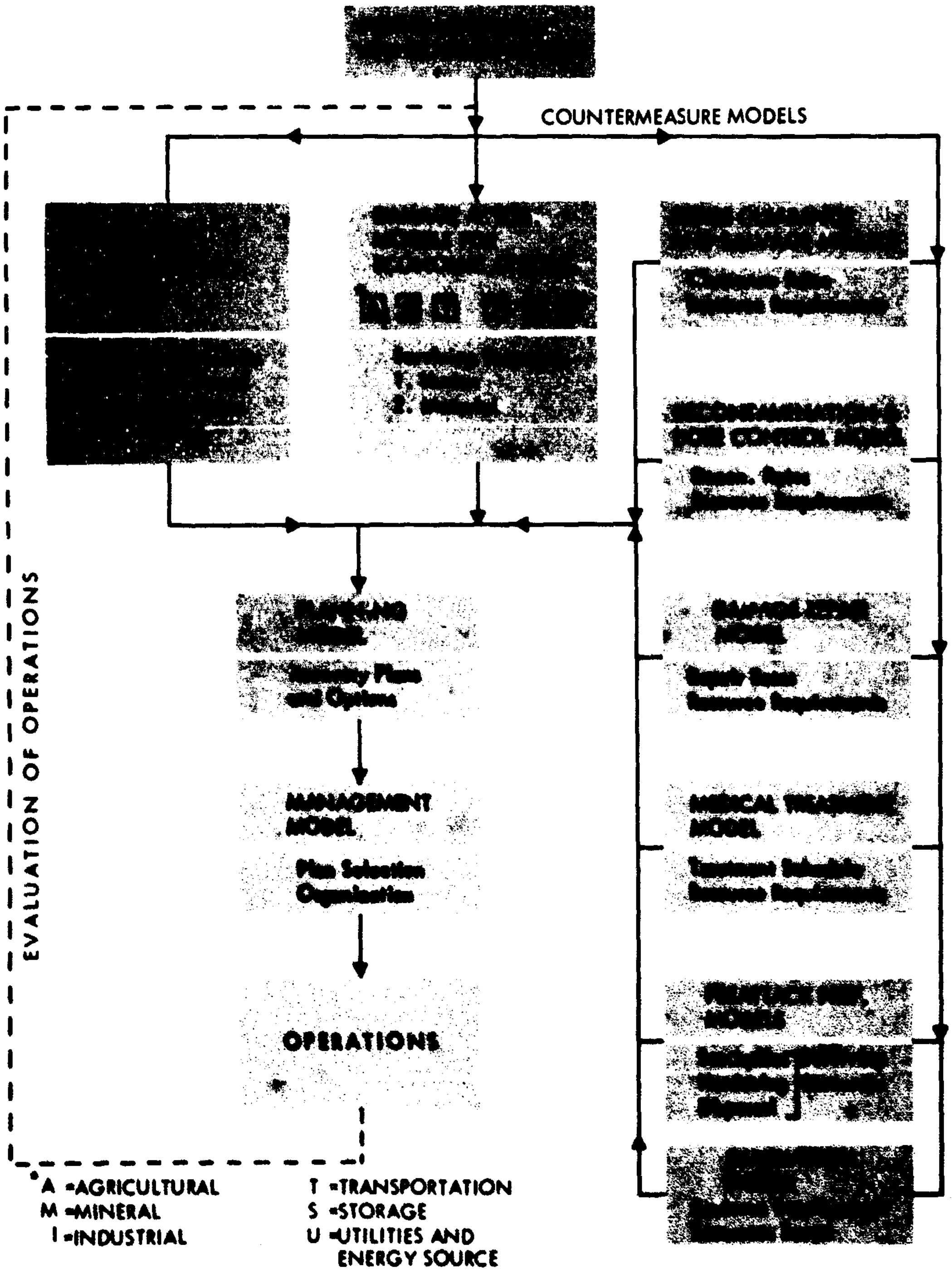
Table 1 (concluded)

	Model Development			Typical References
	Good	Fair	Poor	
Civil defense organization models				
Recovery requirements			X	24
Recovery planning			X	24
Recovery management			X	23

Source: Stanford Research Institute

Figure 1

FUNCTIONAL RELATIONSHIPS
AMONG RECOVERY MODELS OF TABLE 1



SOURCE: Stanford Research Institute.

because of the application of countermeasures (mainly of such preattack preparations as protective measures and stockpiling)

The primary output of these models, when applied in damage assessment studies under hypothetical nuclear war situations, would be a summary of the kinds and amounts of recoverable resources or production capabilities (including humans and their skills) and their locations. The relative effect of the countermeasures would be indicated by the increase in the amount of the recoverable resources when the countermeasures are assumed to be employed. (A more complete evaluation includes the effect of production capability on the time and rate of recovery.)

With a few exceptions, weapon models are well developed. Physical effects models have been derived from well-documented weapon field tests[1] for use in damage assessment studies of hypothetical postattack situations. Radiological effects models have been derived both from weapon field test data and from experimentally simulated weapon effects. Weapon effects and vulnerability models, which provide parametric inputs for the three other model types, have been described elsewhere,[1,2] and will not be discussed further here, except in terms of their outputs.

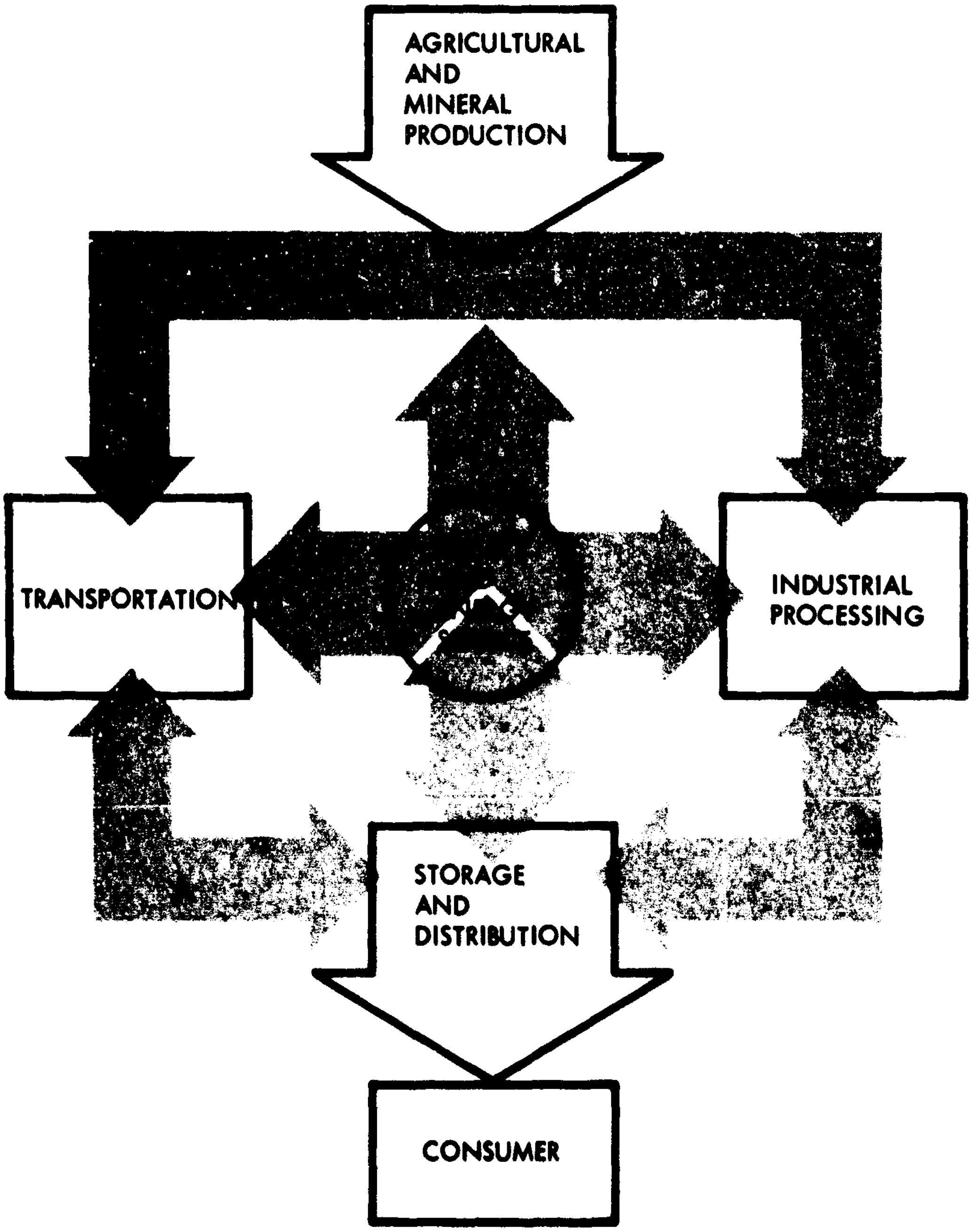
Economic System Models

Economic system models, whose functional relationship is shown in Figure 2, describe the current operation of the U.S. economy. The definition and scope of these models are described below to clarify the functional boundaries for further detailed development.

1. Agricultural production--the combination of human resources with material and energy inputs to produce raw materials used as inputs to industrial processing. Processed agricultural production may consist of either food items (packaged, frozen, canned, etc.) or nonfood items (textiles, fibers, chemicals, lumber, etc.).
2. Mineral production--the combination of human resources with material and energy inputs to produce inanimate materials used as inputs to industrial processing. (All raw materials are of either agricultural or mineral origin.)
3. Industrial processing--the combination of human resources with material and energy inputs to produce a product.
4. Transportation--a vehicular system by which people or materials are moved from one location to another.
5. Storage--the retention of a product during or between processes in its production or distribution for consumption.

Figure 2

FUNCTIONAL RELATIONSHIP OF ECONOMIC SYSTEM MODELS



SOURCE: Stanford Research Institute.

6. Distribution--the planned movement of a product to the ultimate consumer.
7. Utility and energy source--an input (electricity, fuel, etc.) essential to all economic systems for conduct of their respective functions.

Within the above defined scope, the outputs of the economic system model must include estimates of degraded postattack production due to the interaction between inputs essential for production for a range of postattack environments. These degraded production capabilities must be known if recovery requirements are to be met through the planned application of countermeasures. Some of the normal inputs, parameters, and damage criteria for the six economic system models of Table 1 are discussed below.

Agricultural Production Models

Agricultural production models estimate the production potential of the agricultural industry in the postwar period and, through other related models, to make estimates of the contamination levels of farm produce. Currently available models are rather simplified representations based on average crop yields by county and on average soil properties by county. These models require updating and extension so that other related inputs and parameters can be taken into account in the assessments. Some inputs and parameters are: (1) soil amendments, (2) fuel and electricity, (3) equipment, (4) manpower, (5) fertilizers and insecticides, (6) climatic factors, (7) farm management practices, (8) available shelter for animals and humans, (9) seasonal variation of production, (10) preattack preparations, and (11) alternate cropping sequence. Damage criteria from weapon effects models (fire and lethal or debilitating radiation dose to crops, animals, and humans) and countermeasure requirements (decontamination and repair) must be related to establish postattack work routines (planting, harvesting, and animal husbandry) and for estimating potential agricultural production in the postattack period.

Mineral Production Models

Mineral production models are used to assess the production potential of raw materials other than agricultural production in the postattack period. Little has been done to develop these models, although much input data are available. Some input and parameters for these models are: (1) fuel and electricity, (2) equipment, (3) manpower, (4) explosives, and (5) preattack preparations. Mineral production operations are frequently located in remote areas and some are underground. Thus, except for

possible shortages of some external inputs such as fuel, electricity, and explosives, these operations should be more readily recoverable than many others. Underground facilities could also be used to provide fallout protection to operators and to workmen and their families. The characteristics of mineral production do not include the problems of spoilage before consumption, as is the case with agricultural products. Some mineral fuels (petroleum, coal, natural gas) are vital inputs to other systems and, indirectly, to themselves.

Industrial Processing Models

Industrial processing models are used to assess the effects of nuclear attack and civil defense countermeasures and operations on the postwar production potential of vital industries. Although industries are similar in many respects (men, materials, and equipment combining to produce a product), individual differences in these inputs must be defined in the model for each industry with respect to (1) system description giving input-output rates for all materials, services, and energy (including manpower); (2) vulnerability functions for all vital system components and variations in those functions because of protective measures; (3) preattack preparations such as component hardening, stockpiling of spare parts and materials, and the like; (4) applicable postattack recovery procedures; and (5) the data base for the current and future systems.

Some of these models have been designed to describe the normal functioning of the economy, and preliminary simple designs for recovery models have been developed.[11,12,13,15] However, the major portion of the recovery model development remains to be accomplished. Further development of these models, especially for the case of targeted urban areas, is probably the most important consideration in postattack research for the future. Without objective assessments of the postattack recovery potential of the industrial base, assuming that agricultural production could be achieved more readily if the minimum required industrial base were recoverable, no realistic evaluation can be made of postattack recovery processes and the role of postattack countermeasures in these processes.

Because of the importance of industrial processing in the U.S. economy, a general approach to the development of models of these industries will be given later in this section.

Transportation Models

The transportation models assess the postattack potential of these systems to transport vital goods and people from one location to another

at the times and places required in support of postattack operations and other recovery processes. All modes of transportation are included in the assessment. As individual systems, transportation models would be treated in much the same way as the industrial processing models discussed above.

Movement of goods and people can be considered in terms of flow potentials across boundaries of designated geographic areas (census tracts, counties, states, and so forth) per unit of time, with each area being a sink or source for a specific product or manpower. Allowance for delay times in transit across the area, or for internal processing, and serial addition of these times, as weighted by the flow potential, should provide a basis for estimating when specific products would reach the consumer--for example, when flour made from wheat grown in a given county in Minnesota would appear at a city in the state of New York.

Storage and Distribution Models

Storage and distribution models fulfill the same function as the industrial processing models. However, these models are generally simpler in that no change in the products occurrs within the models. Storage locations and distribution points would be sources of stockpiles of various materials and products. Little formal treatment of these models has been accomplished, except for some stockpile development and a few investigations of local food distribution systems.[15,25]

Utility and Energy Source Models

The function of the utility and energy source models is the same as that of the industrial processing models. Although many of these systems (such as water) produce or deliver vital products for use and consumption by humans, most also serve as support systems for other industrial processing systems and provide vital inputs to them. These systems have received more attention than have other systems, mainly on the premise that without availability and recovery of the systems (fuel, electricity, water, communication, etc.), no other system would be operable.

Countermeasure Models

The countermeasure models listed in Table 1 that are functionally related to other types of model systems in Figure 1 are a primary interest and responsibility of the Office of Civil Defense. These models are required for the development of civil defense organization models, and their output will generally serve either as inputs to, or restraints on, other

system models for the purpose of estimating the variation in rate of production from other systems during the postattack period.

Each countermeasure model has a similarity of functional relationships between inputs, internal computations, and outputs. Inputs of situation assessment and surviving countermeasure capabilities are related by model computation to establish the cost-effectiveness of possible alternative procedures or applications of the given countermeasure. Each countermeasure model has a characteristic set of physical units that describe it within the outline of model functions given in Table 2.

Some of the models are well developed (for example, decontamination and dose control) whereas others require clearer definition of input parameters and development of internal mathematical procedures for estimating useful output information. In many instances, useful outputs have not been defined, because virtually no research has gone into defining quantitative relationships among countermeasures systems parameters that apply to various postattack environments. As a first step toward a quantitative description of a countermeasure system, inputs, internal computation parameters, and outputs for some countermeasure models will be described below in greater detail. The order of description is by decreasing current state of model development; no attempt to rank these models according to their importance in postattack recovery investigations has been made because any combination of countermeasures, as a system, may be required in a given postattack situation.

Decontamination and Dose Control Models

Decontamination and dose control models are used to estimate the effectiveness and effort entailed in carrying out radiological countermeasures in the postattack period. These models must have a means (1) to identify the postattack environments in which decontamination is both applicable and required, (2) to estimate the amount of resources consumed, and (3) to estimate the operational effectiveness in terms of advanced recovery times, decrease in exposure dose, or in increased production rates at a given time. A flow diagram of a model to perform these functions is shown in Figure 3.

Key elements of this model are decontamination scheduling and target analysis. Techniques for performing the internal model computation functions of these elements are currently developed to a state where they can be used. Additionally, most of the inputs to the decontamination and dose control model can be obtained from related models or from research findings.

Table 2

FUNCTIONS OF POSTATTACK COUNTERMEASURE MODELS

I Inputs

A. Situation Assessment

1. Preattack description of system components
2. Vulnerability functions for system components
3. Survivor requirements

B. Countermeasure Capabilities

1. Personnel required
2. Equipment and materials required
3. Postattack capabilities

II Internal Computations (for Postattack Situation)

A. Countermeasure Costs

1. Personnel requirements - manhours, dose, skills, locations
2. Equipment and material requirements - amounts, types, locations

B. Countermeasure Effectiveness

1. Lives saved
2. Recovery time saved
3. Radiation dose conserved
4. Production rate achieved

III Output

A. Alternative feasible countermeasures procedures and sequences

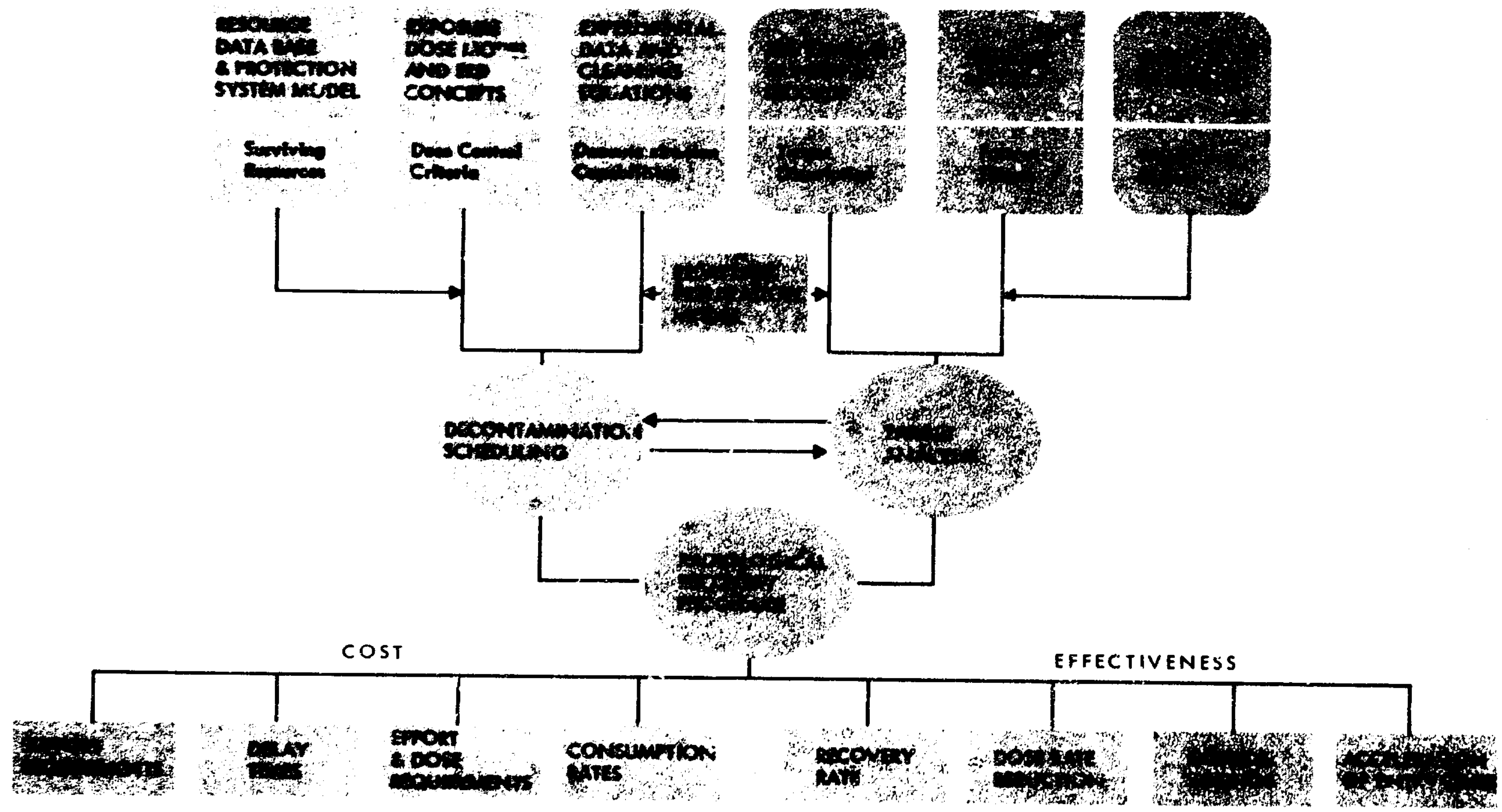
B. Cost of procedures for recovery management use

C. Effectiveness of procedures for recovery management use

Source: Stanford Research Institute

Figure 3

DECONTAMINATION AND DOSE CONTROL MODEL



TO RECOVERY PLANNING

SOURCE: Stanford Research Institute.

Debris Clearance and Salvage Models

The debris clearance model is used to estimate the effectiveness and effort entailed in carrying out debris clearance operations in target areas exposed to the immediate effects (blast and thermal) of nuclear explosions. Three general types of debris clearance operations need to be considered in the postattack period: (1) early-time clearance of transportation routes, (2) early-time clearance of access ways to vital facilities, and (3) later removal and disposal of debris.

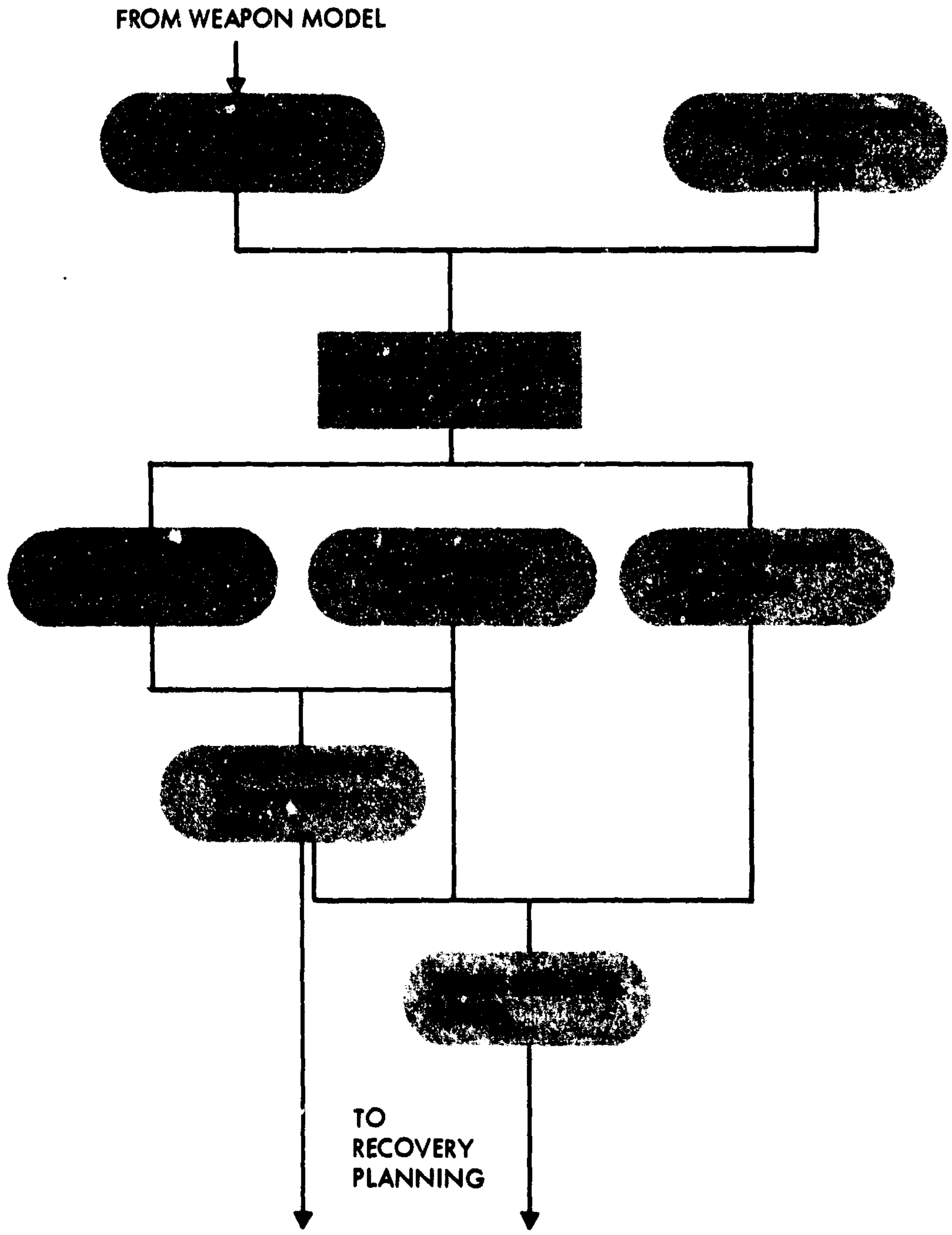
Only limited information has been developed on the formation and distribution of debris from blast and fire effects and on procedures for debris clearance. Target vulnerability functions and debris production submodels describing the type and distribution of debris are needed to provide inputs to the debris clearance model. These inputs must be consistent with the normal sequence and characteristics of events, with respect to debris production following weapon detonation. These events, relative to a structure, are: (1) the structure is bathed in a thermal flux: (2) ignition may occur at this time; (3) the blast wave envelops the structure; (4) ignited materials may or may not continue to burn; (5) the structure is damaged by the blast wave and the degree of collapse and the type and distribution of debris depend on the blast pressure and the type of structure; (6) the debris or the structure may continue to burn, be ignited, or be reignited; (7) upon ignition, burning may cause further structure collapse; (8) additional debris may be cast into the street; and (9) the volume of the debris may be reduced by further burning.

Debris clearance and debris removal effort depends on the amount and nature of the debris and on available clearance and removal equipment. In general, debris that has been reduced to rubble is the easiest to remove whoreas large steel members of semicollapsed structures are the most difficult. The location of debris (on site or off site) is important in estimating effort requirements for early-time debris clearance activities and is a basic parameter of the internal model computations. The characteristics of a debris clearance model are shown in the flow diagram of Figure 4.

Salvage models apply to useful material and equipment in damaged areas and the removal of this material and equipment to other areas of need. Salvaged materials and equipment obtained from debris clearance activities may expedite or make possible the repair or replacement of damaged critical items. The salvage model would provide estimates of the effort required (men, materials, equipment) to use surviving materials and equipment at the same site or another site to help meet the requirements of damage repair.

Figure 4

DEBRIS CLEARANCE MODEL



SOURCE: Stanford Research Institute.

Damage Repair Models

Damage repair models are used to estimate the manpower, equipment, and supplies needed to repair damaged facilities. Structural repair requirements may be similar for many facilities in the same sense that decontamination and debris clearance are widely applicable. However, repair requirements for recovery of industrial production are facility- or industry-oriented and depend on operational characteristics of components in terms of their sensitivity to the effects of nuclear weapons. Operational characteristics of facilities and industries vary so widely that weapon effects vulnerability functions are needed for specific facility, component, and equipment.

Some industries have been assessed for their vulnerability to weapon effects, but many more must be considered before the postattack production potentials of even a limited number of essential survival items can be evaluated. A flow diagram for a damage repair model is shown in Figure 5. This presentation of the model functions is in general terms, recognizing that facility-oriented models in much greater detail will be needed.

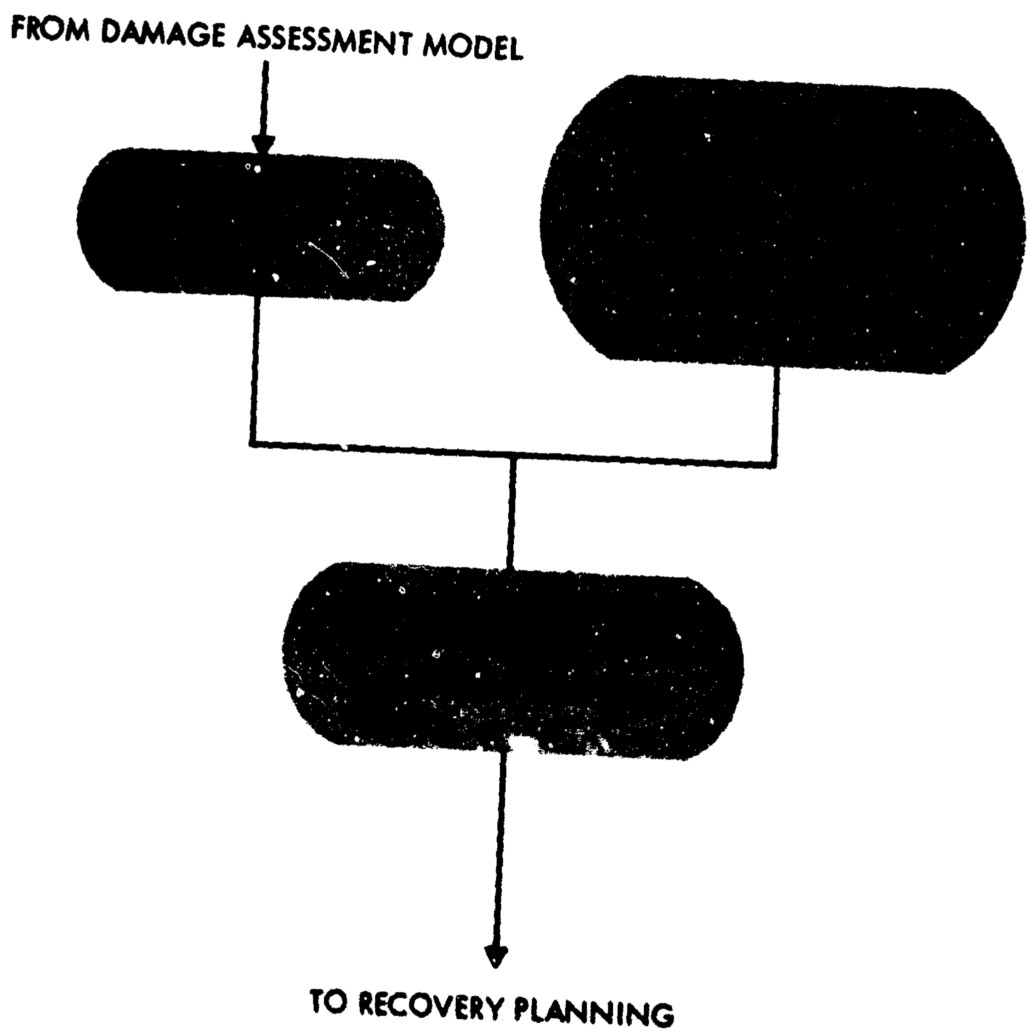
Medical Treatment Models

Medical treatment models provide estimates of the effectiveness and effort of countermeasures for administering medical treatment to the survivors in the postattack period. Treatment for specific weapon effects injuries is well understood, and if treatment capabilities are available, the methods can be effectively given to a limited number of patients. However, in the early postattack period, when the patient-to-doctor ratio may be very high in some areas, it is possible that the management of medical treatment could be improved through the use of models for estimating medical treatment requirements. Some input, output, and other parameters for these models are: (1) injury from direct weapon effects on people, (2) injury from environmental damage (structure collapse, missiles, fire), (3) injury from radiation exposure, (4) illness and injury not related to the attack, (5) resource requirements (skills, supplies, facilities) for treatment of injured survivors, (6) resources (medical supply stockpiles, hospitals) available to meet needs of survivors, and (7) degraded treatment procedures and triage techniques to permit the most timely use of surviving resources.

Some of the relationships that need to be established among weapon effects injuries, communicable diseases, chronic ailments, and treatment requirements are shown in Figure 6. The model must be able to estimate stochastic medical treatment requirements, mostly for weapon effects injuries at early postattack times and for control of epidemics of

Figure 5

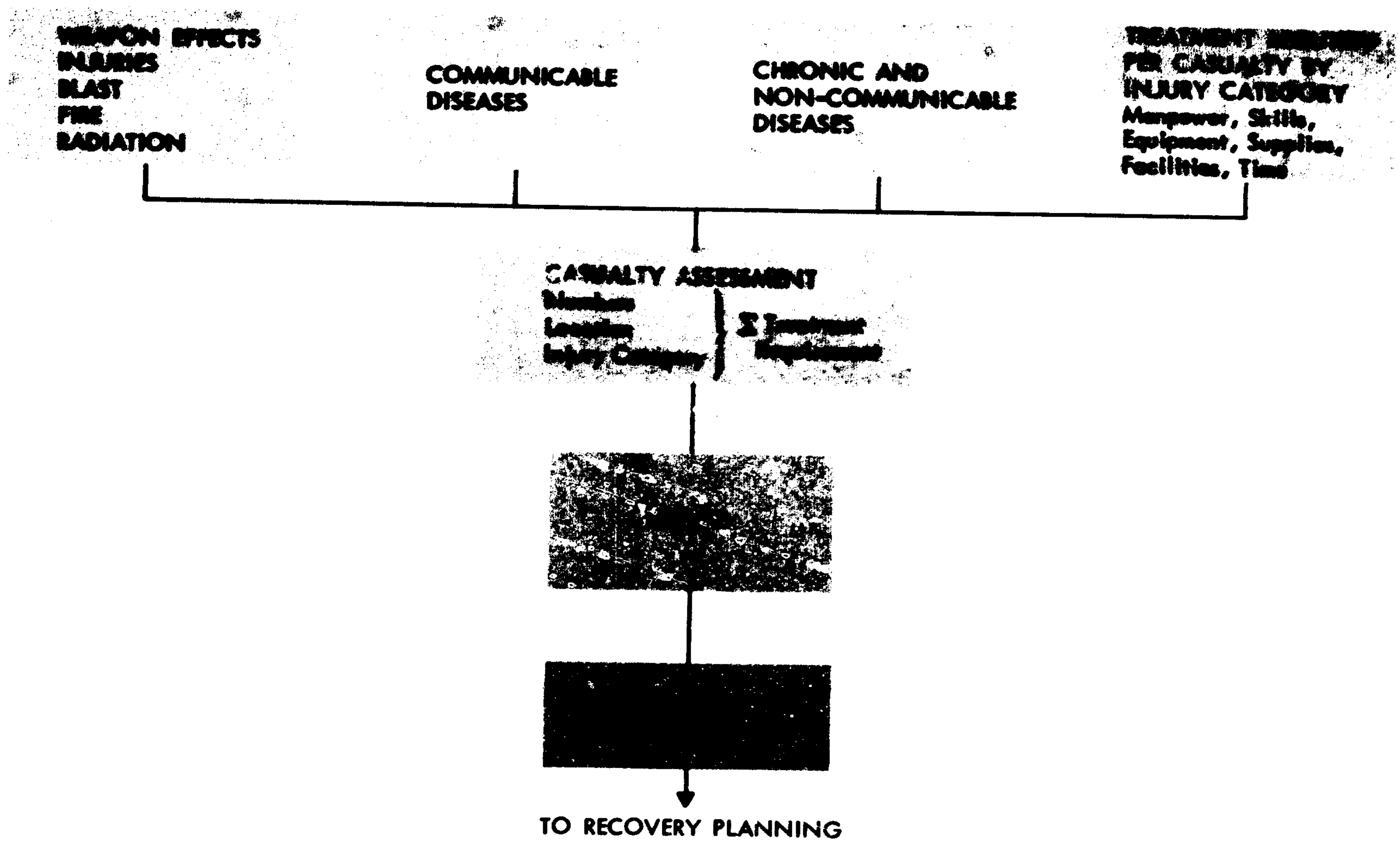
DAMAGE REPAIR MODEL



SOURCE: Stanford Research Institute.

Figure 6

MEDICAL TREATMENT MODEL



SOURCE:Stanford Research Institute.

communicable diseases at later times while providing chronic or routine treatment to the extent possible at all times.

Evacuation Models

Evacuation models are used to examine the cost-effectiveness of operations in which human or material resources are moved. Evacuation of people may be for their initial survival; however, this action also includes the sustenance of the evacuees as well as their integration into the surviving economic and social structure at their destination.

Studies of evacuation (or remedial movement) have been made for several phases of nuclear attack. These studies have been concerned with specific time periods before, during, and after attack without consideration of later activities of the evacuees. Some inputs and parameters of these models are: (1) location and types of threats to the surviving population, such as fire, radiation, starvation and thirst, exposure to elements, sickness, and injury; (2) surviving evacuation capabilities, such as personnel, equipment, and supplies available; and (3) destination requirements for short term needs, such as medical treatment, feeding, and housing, or long term integration of evacuees, such as manpower utilization for recovery and continued production, economic self-support, and social coalescence.

Expected outputs of these models are: (1) alternative evacuation procedure costs, (2) number of evacuees at old and new locations, and (3) cost-effectiveness of alternative evacuation procedures (materials or man-hours per life saved or unit of increased production - or all).

Preattack Preparation Models

Preattack preparation models provide quantitative estimates for preattack preparation requirements for stockpiling, hardening, and dispersing material resources that may be in short supply in the early postattack period. These models would be used to examine the requirements and effectiveness of these countermeasures in recovery processes and, where feasible, to provide cost-effectiveness information for preattack planning. The model details would consider reductions in vulnerability and the consequent increase in resources for these countermeasures.

The preattack preparation models should also provide information on the character and size of the organization needed to manage the countermeasures.

Civil Defense Organization Models

Civil defense organization models consist of the recovery requirement models, recovery planning models, and recovery management models. These three models are used to coordinate the outputs of all other recovery system models and to supply feedback information on operational constraints. The scope of these models is defined briefly below.

Recovery Requirement Models

Recovery requirement models identify the systems that must be recovered and provide estimates of the minimum production requirements, including the latest time after attack when the system must be operable. The criteria, or model constraints, include individual and aggregate needs for continued survival of the population (healthy people and casualties) as minimum requirements and those imposed for support of national goals (for example, military requirements).

Typical inputs and parameters are number, location, and status of survivor groups; essential survival items and their necessary and desirable consumption rates; and surviving stockpiles of these items.

Recovery Planning Models

The functions of the recovery planning models are to estimate the feasibility of recovery operations, to develop alternative plans and schedules for feasible operations, and to provide operating information for use in selection of plans by management.

Formalized recovery planning methods have been developed only for radiological recovery operations (as decontamination manuals, and so forth). Similar formalizations are needed for other postattack recovery operations and for postattack countermeasure systems. The detailed methods, however, may require some degree of alteration and adjustment to accept inputs from the recovery requirement models. The recovery planning models are concerned with the details of data processing that would be carried out as staff functions of a civil defense organization concerned with operational planning. The original inputs consist of damage assessment data that would be obtained from damage assessment models for research, but under attack conditions would be obtained from observation reports.

Recovery Management Models

Recovery management models are used to assess the relative effectiveness of alternative postattack recovery plans and operations and to develop

decision guidance and organizational characteristics for the management of postattack operations. These models will accept inputs from all other models and exercise them, using various assumed kinds and weights of attack and assumed postures of alternative feasible postattack countermeasure systems.

Outputs from these models should lead to sets of production rate curves for assessing the relative effectiveness of recovery routines, the gross cost of postattack countermeasures relative to the cost of other countermeasures, the gross size and composition of a postattack recovery force, support requirements for countermeasure systems (information, communications, equipment, supplies, and manpower), command and control requirements, description of system bottlenecks, and requirements of preattack preparations for making the recovery of specified postattack situations feasible.

Parameter Limits of Models

Each model described above is functionally limited in scope by its interface with associated supporting models as shown in Figure 1. The principal reason for this defined limitation is to permit a systematic development of each specific model without carrying postattack research to an unmanageable degree of complexity in which every parameter depends on all others with no limit of variability.

Within any model, each parameter has limiting values. For economic system models and preattack preparation models, these limits are related to the physical characteristics of system components that determine the overpressure at which either destruction or no damage occurs, the thermal radiation flux at which fires start, or the exposure dose at which operations are either unrestricted or impossible at a given time. Postattack countermeasure model parameters describing performance characteristics are also limited by physical effects on men, equipment, and materials. These limitations, in turn, limit the recovery that may be achieved in a given time. On the other hand, a conservative application of postattack countermeasures would tend to be limited by the scheduling requirements for production recovery. The scheduling of production recovery for economic system components and operations is therefore a major concern in postattack recovery planning and management.

GENERAL APPROACH TO MODEL DESIGN AND DEVELOPMENT

One approach to the design of recovery system models (with special reference to the industrial processing models) is discussed in this section. The model development techniques that include linear flow diagrams, description of elements, and expanded flow network lead to models of operational systems. As examples, water and bread systems are outlined and described by using these techniques. A flow diagram for utilities, an important if not essential input to all industrial process models, is shown in Figure 7.

Linear Flow Diagram

The initial representation of any given system for model development is a simplified flow diagram. Such a diagram consists of a series of boxes that illustrate the linear sequence of flow of major elements (materials, products, energy, and so forth) along the main path of movement through the system. Each box carries the title of a major element or a major process that may or may not be composed of several minor elements and processes.

Description of Elements

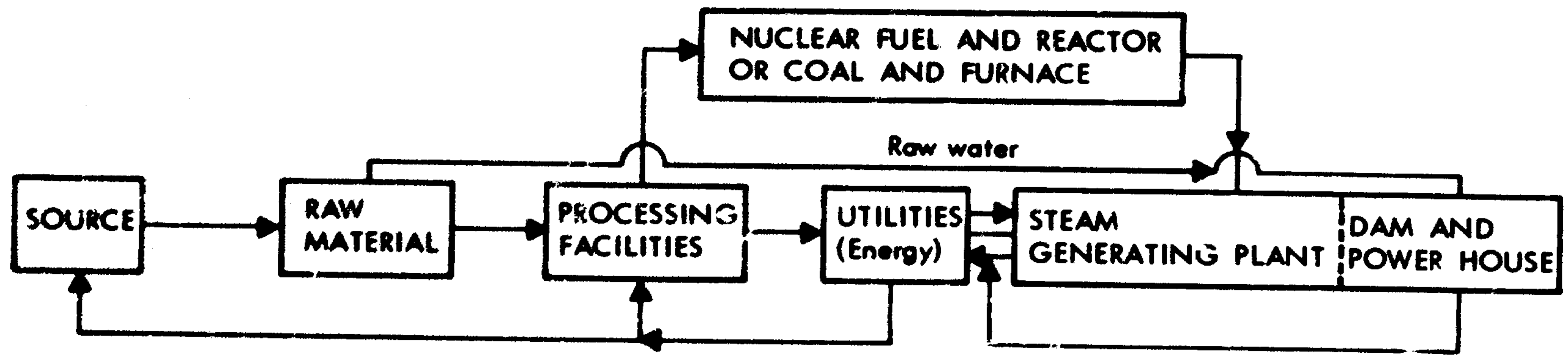
Major elements and processes for each box in the flow diagram, as well as the composition of minor elements, are identified and described as to kind, amount, properties, specifications, flow rate from box to box, delay times, exchange rates (in terms of entry into the system), and other factors considered important in the operation of the system.

Expanded Flow Network

The simplified flow diagram and the description of elements provides the basic framework for developing a system network that links all the various elements into a continuous working system. The expansion includes subsystem and subelement networks required to illustrate the processes and their supporting systems.

Figure 7

LINEAR FLOW DIAGRAM FOR UTILITIES



Oil field	Crude oil	Refinery	Fuel*
Gas field	Gas	Pump station	Natural gas
Lake, stream, ocean	Raw water	Treatment plant	Water
Mines		Beneficiation	Coal
	Coal Uranium ore	Beneficiation by recovery and fabrication	Electricity

Energy conversion of fuels and water into still another utility

* Fuel is not traditionally a utility but is in that class functionally.

SOURCE: Stanford Research Institute

Operational System Models

The major system models consist of mathematical descriptions of the operations and the logistical aspects of each element of the system. Essentially, this effort includes the collection and reconstitution of data required for description of the elements, as given above. The descriptions are formulated so that vulnerability functions can be applied in damage assessment computations for making estimates of changes in various input and output parameters, in addition to the loss in capacity itself given above.

In practice, the operational models are developed for a given type of system with "open" inputs and outputs to resources, support systems, or other systems. These inputs are closed when other models are developed in sequence or by damage assessment data when an attack condition is applied.

Model Design for Water and Bread Systems

Processing model flow diagrams have been outlined for two systems--water and bread. The bakery element, as a subsystem to the bread network, is described in some detail as part of the second example.

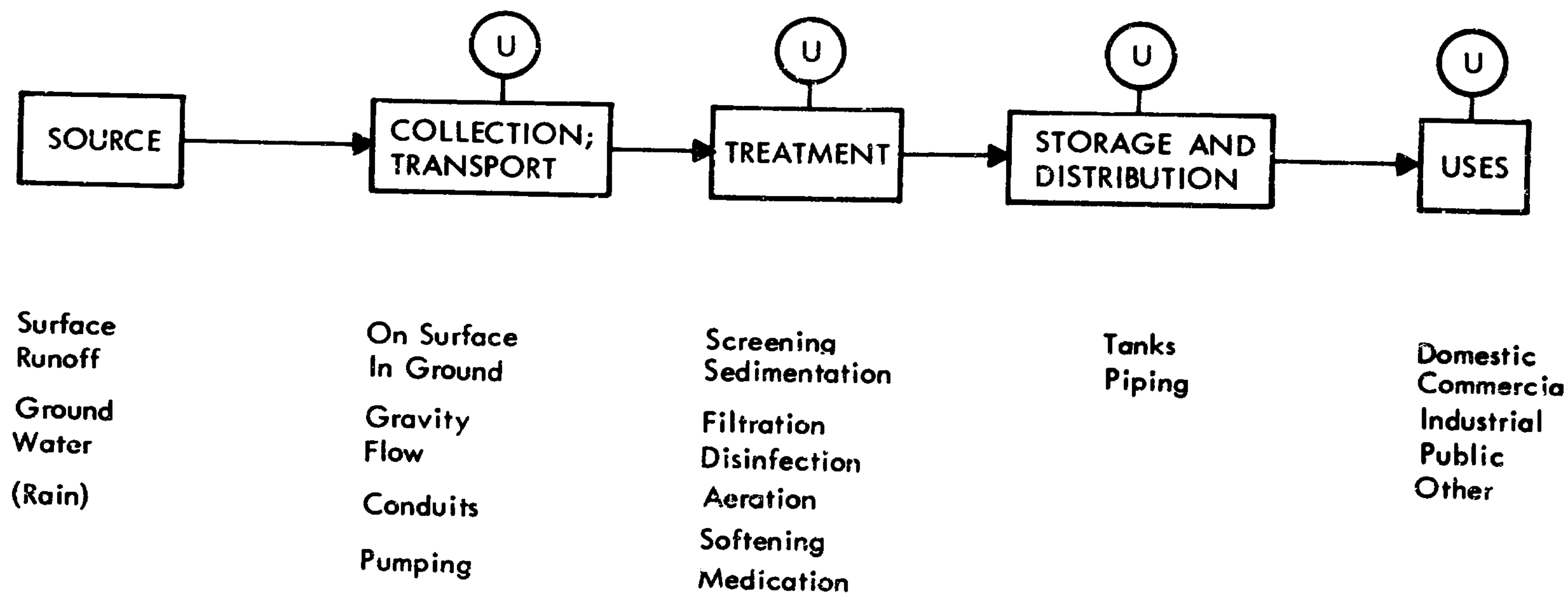
Water System

A linear flow diagram for the major functional elements of a water system is shown in Figure 8, with a listing of component minor elements whose specific functions are described in Table 3. An expanded system network for water, showing the source of minor elements, is given in Figure 9. A typical water treatment subsystem network is shown in Figure 10, and daily per capita requirements for water are given for normal and emergency conditions in Table 4. These figures and tables define the operating characteristics of the normal water system on which the effects of a nuclear attack can be superimposed.

Vulnerability models for the water system components can be generated from information on the sensitivity of the water system component to nuclear weapon effects such as that given in Table 5. Vulnerability functions in the case of blast damage would consist of the overpressure at which specific components fail. For a specified attack, the overpressures at all water system component locations could be computed from weapon effects models. The type and number of undamaged, damaged, and destroyed components may then be summarized, and the recovery requirements may be estimated in terms of repaired or replaced components, with associated inputs of material, labor, and equipment.

Figure 8

LINEAR FLOW DIAGRAM FOR WATER



NOTES:

1. Major elements (or classes of elements) for the system are contained in the boxes with lesser elements listed beneath.
2. A circled U signifies utilities required.
3. Excludes brackish and salt water (see Figure 9).

SOURCES: Stanford Research Institute and Reference 25.

Table 3

DESCRIPTION OF WATER SYSTEM ELEMENTS

Source

Surface: Runoff from rain and snow melt--lakes, reservoirs
Ground: Natural springs, wells, infiltration galleries
Rain: Not widely used--domestic systems

Collection; Transport

On Surface: Lakes, conduits, pumping stations, reservoirs-dams
In Ground: Wells, pumps--6- to 24-inch diameter, 50 to 3,000 gpm
Transmission: Canals, tunnels, pipes
Pumping stations: Electric motors, automatic operation

Treatment

Screens: Bars for coarse materials
Plain Sedimentation: 1 to 10 hours for 50 to 80 percent suspended solid removal
Chemical Sedimentation: Flocculating agents--alum
Filtration: Bacteria-free water--sand filters, anthracite filters
Disinfection: Chlorine
Aeration: Taste and odor removal--spraying, charcoal absorption
Softening: Zeolite--hardness removal
Medication: Fluoridation

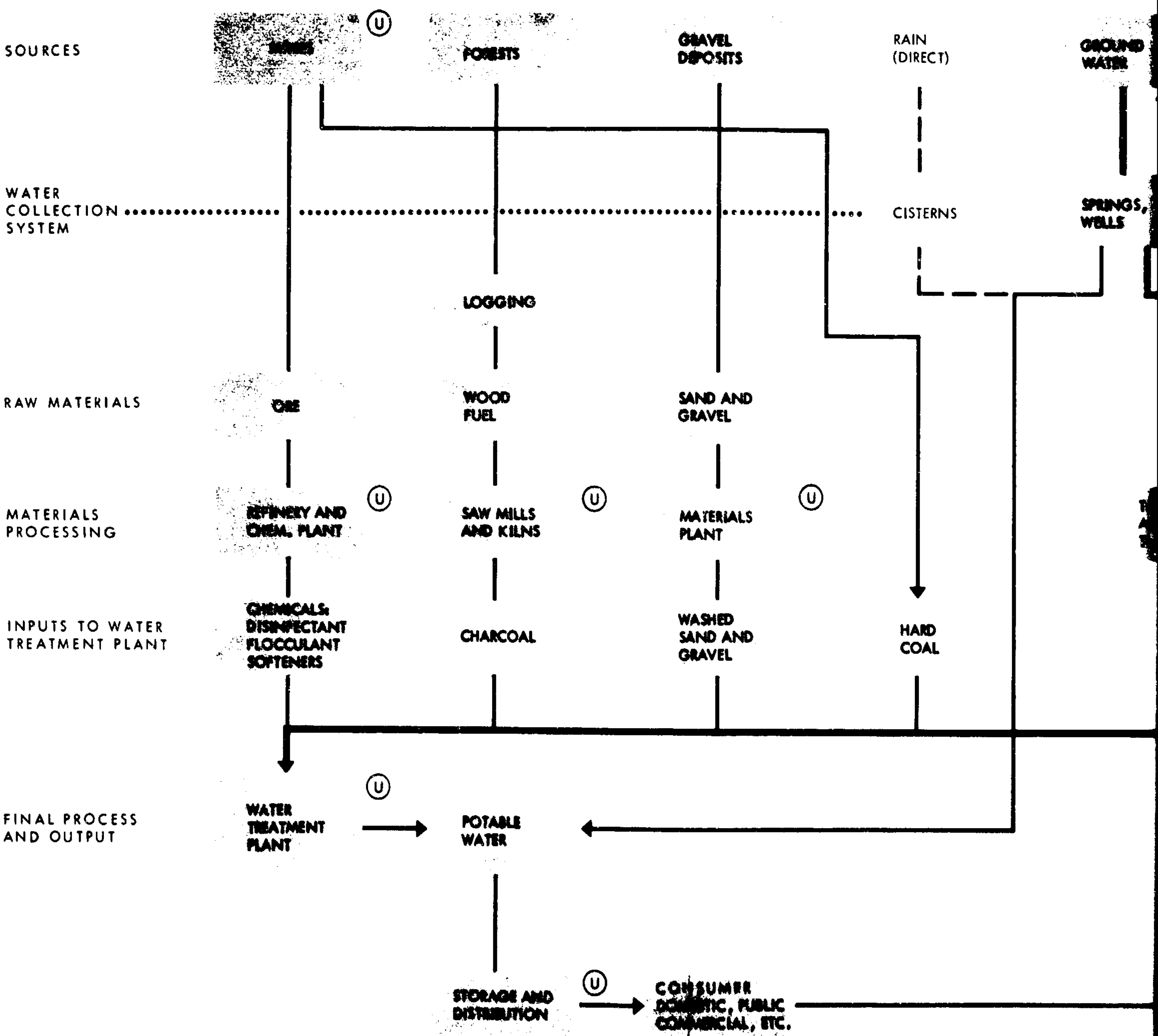
Storage and Distribution

Tanks--elevated and ground storage
Piping system--low pressure, high pressure
Demand and pressure control

Sources: Stanford Research Institute and Reference 26

Figure 9

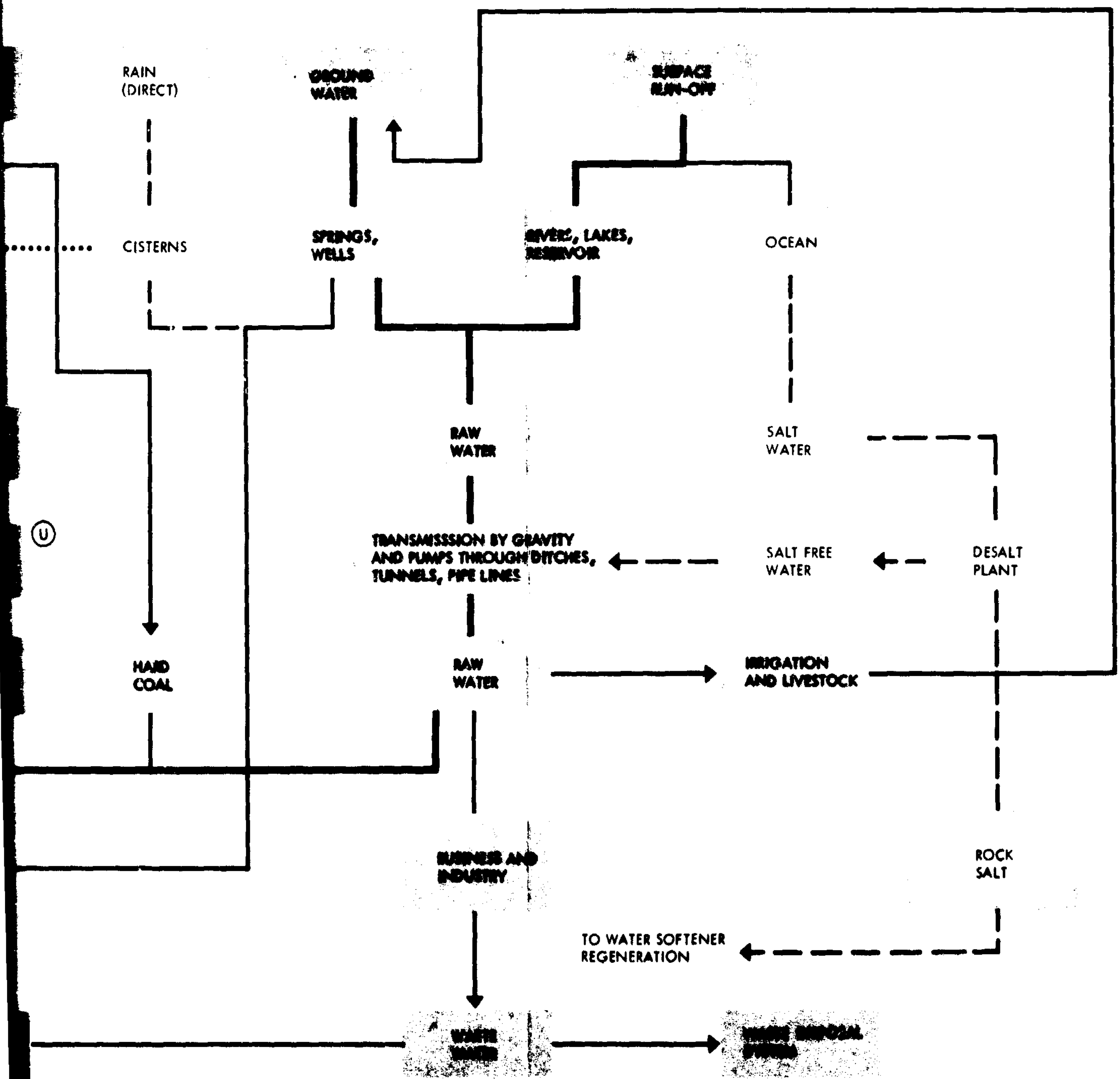
EXPANDED NETWORK FOR A WATER SYSTEM



NOTE: (U) SIGNIFIES UTILITIES REQUIRED

SOURCE: Stanford Research Institute.

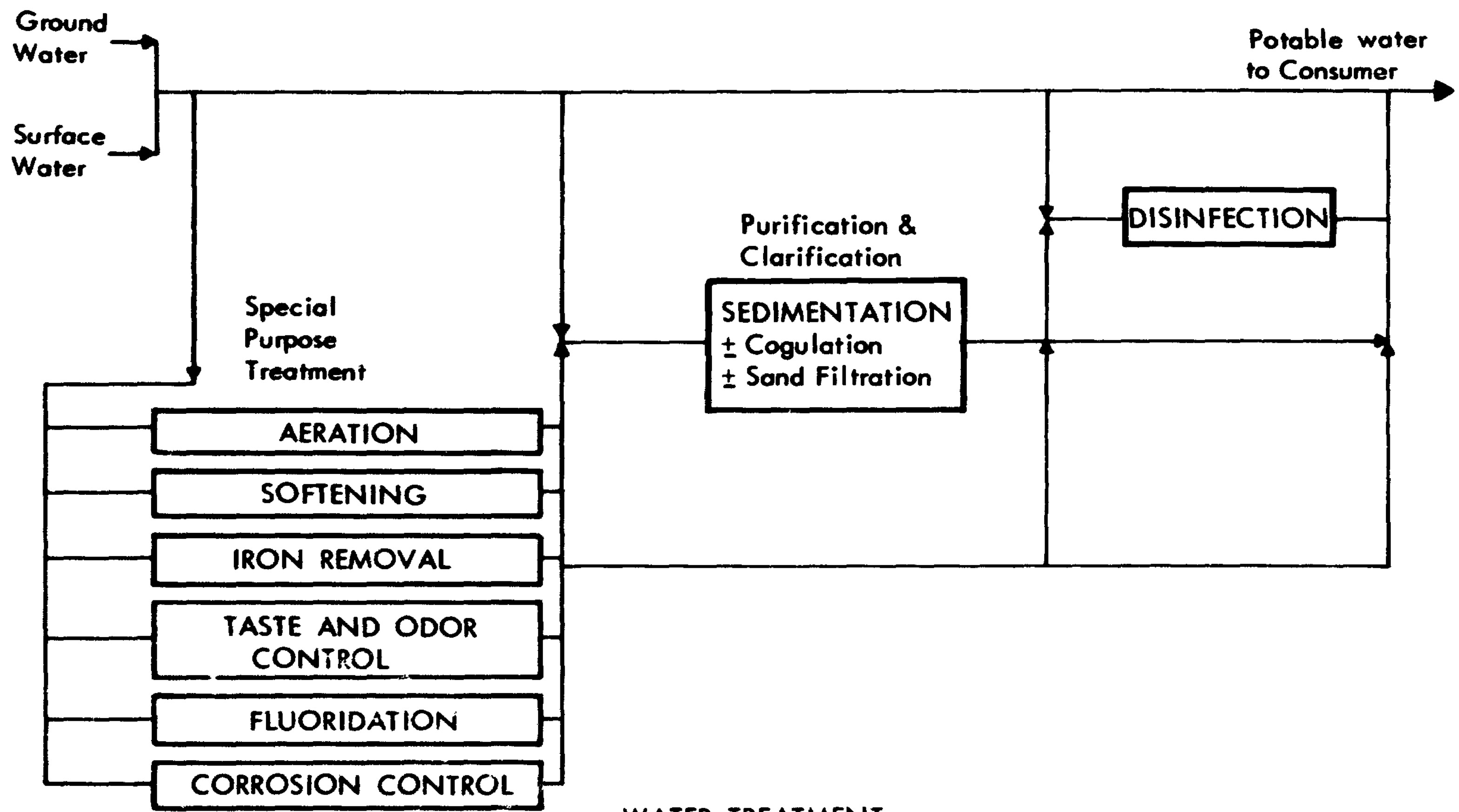
A


RAIN (DIRECT)
GROUND WATER
SURFACE RUN-OFF
CISTERNS
SPRINGS, WELLS
RIVERS, LAKES, RESERVOIR
OCEAN
RAW WATER
SALT WATER
U
TRANSMISSSION BY GRAVITY AND PUMPS THROUGH DITCHES, TUNNELS, PIPE LINES
SALT FREE WATER
DESALT PLANT
HARD COAL
RAW WATER
IRRIGATION AND LIVESTOCK
BUSINESS AND INDUSTRY
ROCK SALT
TO WATER SOFTENER REGENERATION

B

Figure 10

TREATMENT SUBSYSTEM FLOW DIAGRAM FOR WATER



SOURCE: Reference 26.

WATER TREATMENT
COMBINATION OF PROCESSES

Table 4

PER CAPITA REQUIREMENTS PER DAY FOR WATER

Water Use	Consumption (gal/man-day)	
	Normal	Emergency
Drinking and cooking	4	4
Laundry	6	1
Bathing	5	1
Toilet	5	2
Other domestic	40	2
Total	60	10[a]

a $\simeq$ 1/6 normal total

Source: Reference 26

Table 5

SENSITIVITY OF WATER SYSTEM COMPONENTS
TO NUCLEAR WEAPON EFFECTS

	Blast	Fire (Thermal)	Fallout
More Sensitive	1 psi Elevated tank roofs Glass chlorinator chambers Chlorine feeder components	Structures Equipment Supplies Forests	Operators Water contamination
	2 psi Elevated tanks Tower-type aerators Chemical storage and feeding equipment		
	3 psi Structures housing equipment Home service connections Pumps, motors, and controls damaged by flying debris		
	4 psi Tanks, standpipes overturned Coagulation equipment Grit conveyers and supports		
	6 psi Ground storage tank roofs Filters		
	15 psi Chlorine storage cylinders Heavy pumping equipment Ion exchange equipment Ground-level tanks		
Less Sensitive	25 psi Underground sand-filter galleries		

Sources: Stanford Research Institute and Reference 26

Vulnerability functions for fire damage to water system would relate the thermal flux computed from weapons effects models to the fire susceptibility of system components (principally structures) at a given location. However, because of the probabilistic nature of fire ignition and spread, vulnerability functions for fire damage could not be as consistently defined as blast damage. Vulnerability functions for fallout effects on the water system would relate fallout characteristics at a given location estimated from a fallout model to water contamination and exposure doses to operators.

Bread System and Bakery Subsystem

An important reason for studying the bread system and its recovery in the early postattack period is the potential use of bread as a dietary expedient. About a pound of bread, three times the normal daily per capita consumption, could provide the energy, protein, and carbohydrate requirements shown below.

Energy	Percent of Daily Requirement		
(calories)	Protein	Calcium	Carbohydrate
1,300	67	67	100

The normal preattack operating characteristics of the bread system are given in Figures 11 and 12. Vulnerability models and functions are derived from the component sensitivity listing in Table 6 in the manner described for water systems.

Normal characteristics of the operation of a bakery are illustrated by the flow diagram in Figure 13. A modern bakery of average capacity produces 100,000 pounds of bread a day, which provides the normal daily bread consumption for about 365,000 people. Significant input resources are raw and processed materials, labor, facilities, and utilities. The quantities of ingredients used are approximately proportional to the quantity of bread produced, and to the number of man-hours required in most labor categories.

Estimates of specific rates and capacities for the input resources to a bakery are given in Table 7 on the basis of unit output and an assumed output capacity of 100,000 pounds of bread a day. The nature of the processing equipment requires a larger specific input rate for utilities for less than normal capacity production. Larger specific input rates would occur in situations where any production process of the system does not operate at its normal capacity. (An extreme case would be the use of a 50,000-pound capacity oven to bake one loaf of bread.)

Figure 11

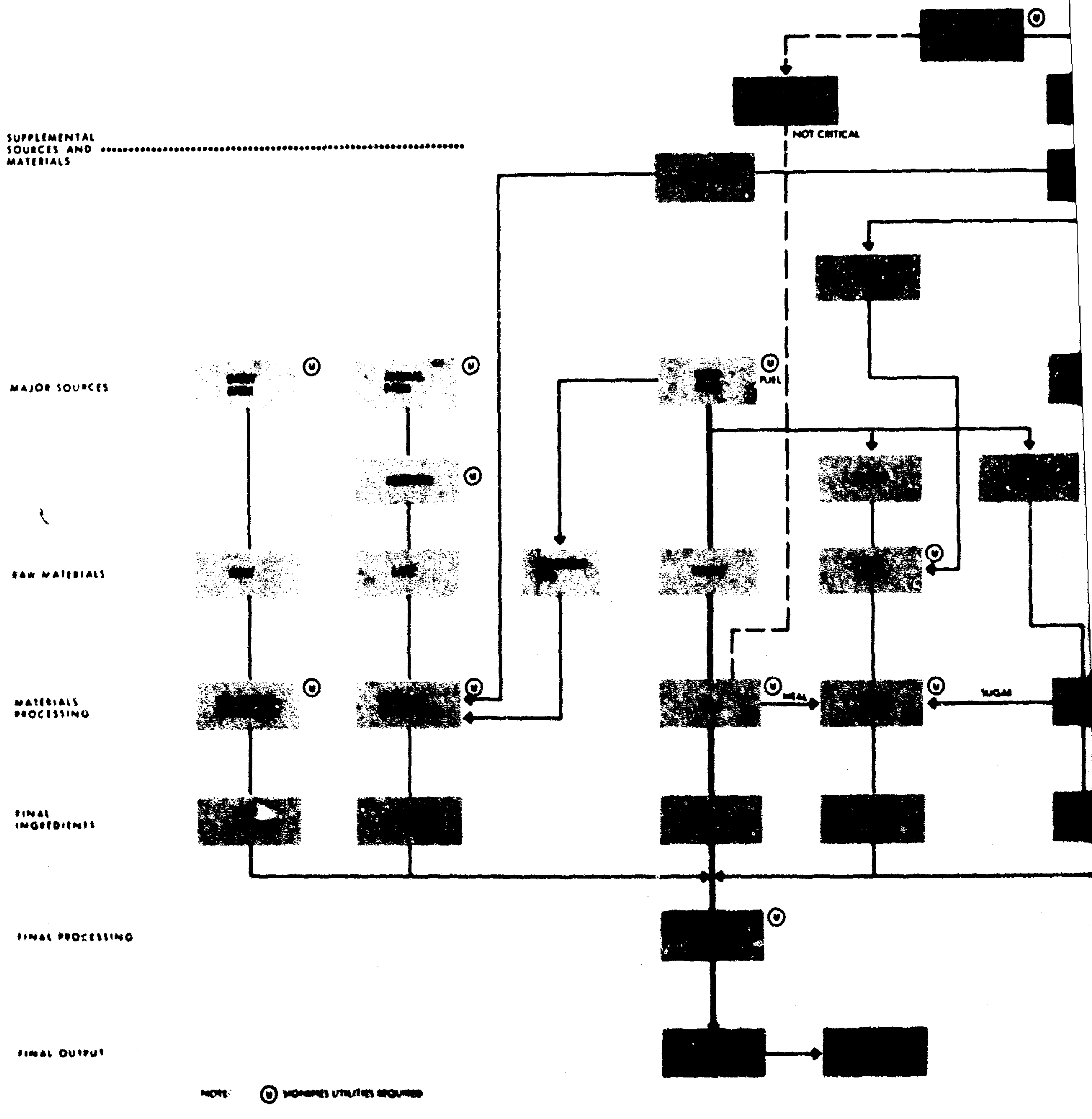
LINEAR FLOW DIAGRAM FOR BREAD A BREAD SYSTEM

Mines (ocean)	Minerals (salt) Chemicals	Refinery Chemical plant	Seasonings Preservatives
Crop Farm	Sugar beets	Refinery	Yeast
	Barley	Malt plant	
	Wheat	Mill (meal)	Flour
	Vegetable seeds	Refinery	
Animal Farm	Livestock (lard)	Rendering plant	Shortening
Dairy Farm	Milk	Condenser-Dehydrator	Milk Solids

NOTE: A Circled U Signifies Utilities Required.
SOURCES: Stanford Research Institute and Reference 27.

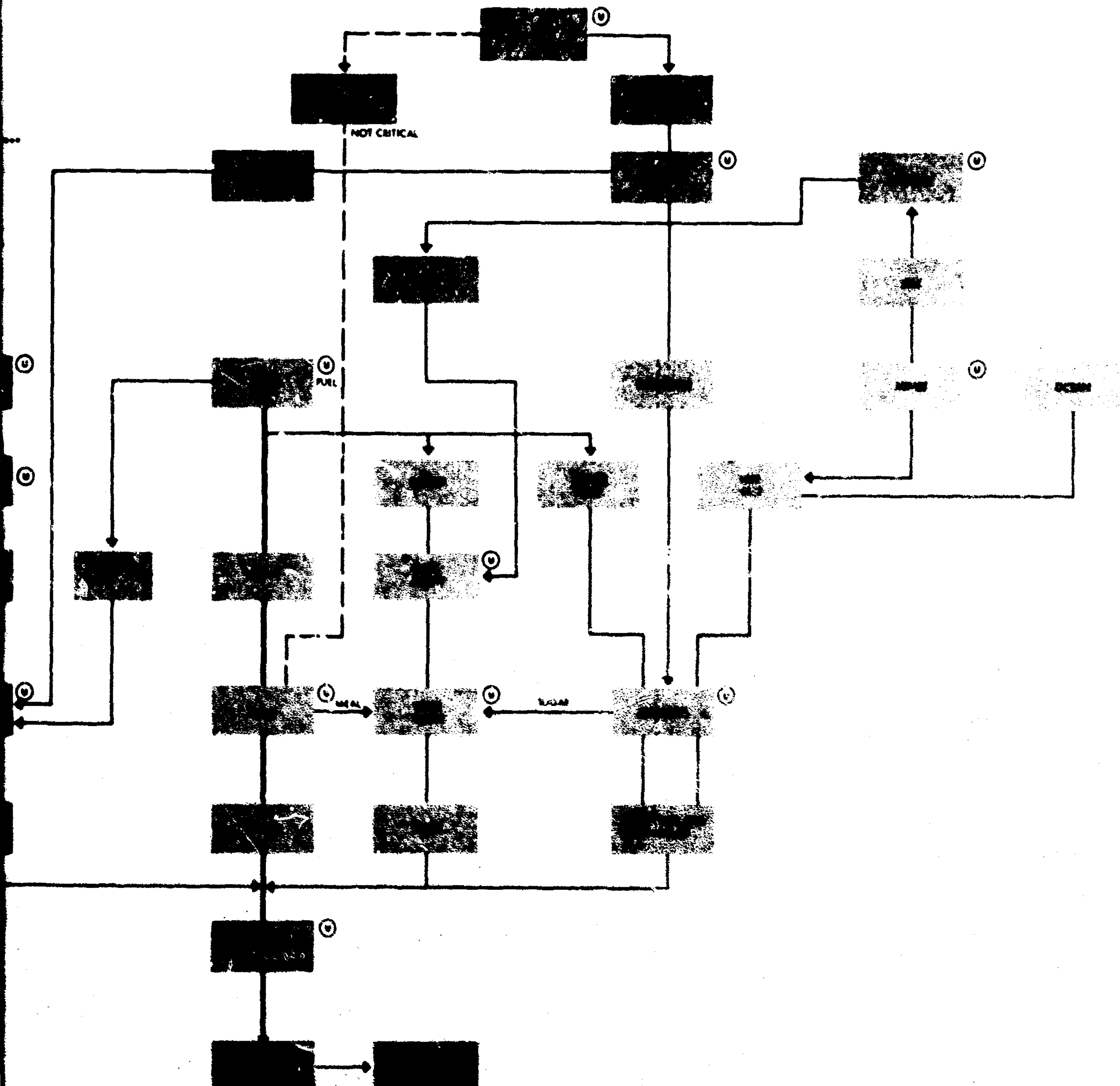
Figure 12

EXPANDED NETWORK FOR A BREAD SYSTEM



A

A BREAD SYSTEM



B

Table 6

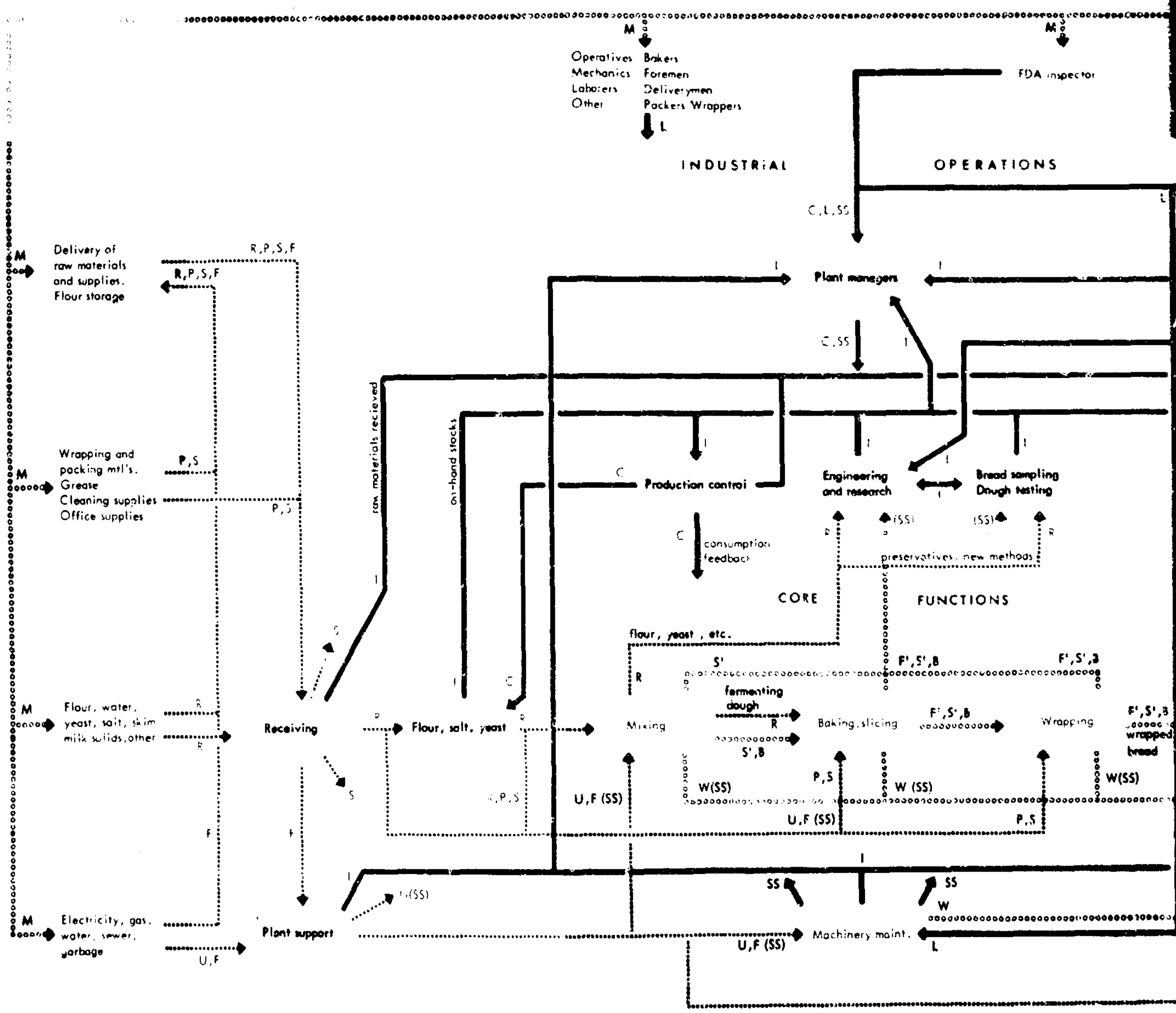
SENSITIVITY OF BREAD SYSTEM COMPONENTS TO NUCLEAR WEAPONS EFFECTS

Blast	Fire (Thermal)	Fallout
Structures	Structures	People
Equipment	Equipment	Animals
Fixtures	Supplies	Crops
Supplies	Animals	
Utilities	Crops	
Transportation		

Source: Stanford Research Institute

Figure 13

BREAD SUBSYSTEM NETWORK FOR BAKERIES



INPUTS ....

R - raw materials
P - process materials
S - supplies
U - utilities
F - fuel
(SS) - support service connected

SOURCE: Stanford Research Institute

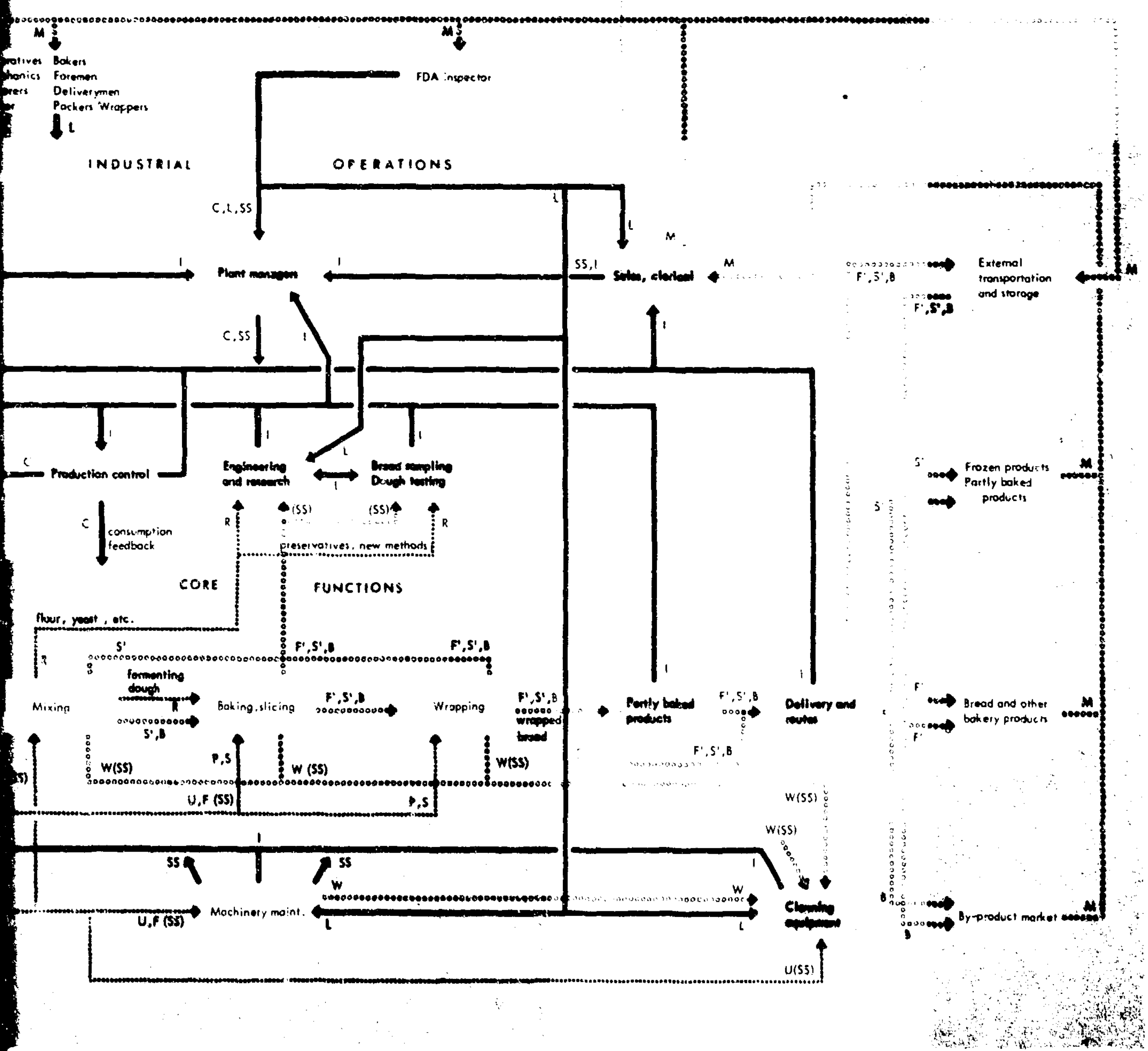
OUTPUTS

F' - finished products
S' - semi processed materials
B - by-products
W - waste products
M - money
(SS) - support service connected

HUMAN RESOURCES

C - command links
L - labor supply
I - information links
SS - support service

BAKERIES



Bakers
Foremen
Deliverymen
Packers Wrappers
FDA inspector
INDUSTRIAL
OPERATIONS
Plant managers
Sales, clerical
External transportation and storage
Production control
Engineering and research
Bread sampling Dough testing
consumption feedback
preservatives, new methods
CORE
FUNCTIONS
flour, yeast, etc.
Frozen products
Partly baked products
Mixing
fermenting dough
Baking, slicing
Wrapping
wrapped bread
Partly baked products
Delivery and routes
Bread and other bakery products
Machinery maint.
Cleaning equipment
By-product market

B

Table 7

ESTIMATES OF SPECIFIC RATES AND CAPACITIES FOR THE INPUT RESOURCES OF A TYPICAL BAKERY

Input	Pounds of Bread per Pound of Input	Pounds Needed per 10^6 Pound Bread
Materials		
Flour	1.85	54,000
Water	2.78	36,000 (~4,500 gal)
Yeast	100.	1,000
Salt	100.	1,000
Sugar	33.3	3,000
Skim milk solids	33.3	3,000
Other ingredients	33.3	3,000
	Pounds of Bread per Man-Day	**Workers per 10^6 Pound Bread**
Labor[a,b]		
Bakers	825	121
Foremen	4,970	20
Delivery men	918	110
Packers and wrappers	2,210	45
Operatives[c]	1,460	68
Laborers[c]	6,640	15
Truck drivers	5,220	19
Mechanics	7,440	14
Other workers	516	190
Total		602
	Pounds of Bread per Unit Day	**Units per 10^6 Pound Bread**
Facilities		
Floor area		
Bakery	--	100,000 sq ft
Warehouse	--	25,000 sq ft
Pneumatic flour bins[d]	--	15
Mixers[b]	50,000	2
Kneading, shaping, and panning machines[b]	72,000	2
Ovens[b]	50,000-100,000	1-2
Slicers and wrappers[b]	50,000	2
Utilities[e]		
Water (cooling, heating, and humidifying)		
Electricity (machinery motors and lighting)		
Gas (ovens)		

a These workers also produce perhaps another 100,000 pounds of nonbread bakery products.

b Sixteen-hour day of two shifts is assumed.

c Not elsewhere classified.

d Storage of perhaps 750,000 pounds of flour, or about a 15-day supply.

e Rates not known in detail but must operate above facilities.

Sources: Stanford Research Institute and Reference 27.

Qualitative descriptions of damage or hazards from nuclear weapon effects and potential countermeasures for use against these effects are presented in Table 8 for a number of bakery subsystem components. The quantitative detail needed for planning and implementing the countermeasures would be part of the input data used in the development of the recovery model system.

Table 8

NUCLEAR ATTACK CONSEQUENCE AND APPLICABLE COUNTERMEASURES FOR THE BAKERY SUBSYSTEM

	Blast	Thermal and Primary Ignition	Secondary Ignition and Fire Spread	Fallout	Rapid/No Shutdown	Countermeasures
Facilities						
Structures						
Process	Direct damage		Direct	Denial		Hardening; decon;
Bakery	Missiles & debris		Direct Damage			Debris clearance
Office (if separate)	Missiles & debris		Direct Damage	Denial		Debris clearance
Warehousing						
Flour storage	Missiles & debris		Direct Damage	Denial		Debris clearance
Process equipment						
Continuous						
Kneading, shaping, & panning						Alternate method
Ovens						Harding
Slicers	Minor missile		Warped machines	Cleanup		Alternate method
Wrappers	damage			problem		Alternate method
Batch						
Mixers						Alternate method
Support equipment						
Materials						
Inputs						
Unprocessed raw materials						
Water (see under utilities)						
Semiprocessed raw materials						
Flour		Dust explosion		Contamination		Closed containers
Yeast					Growth & spoilage	
Salt				Contamination		Closed containers
Sugar				Contamination		Closed containers
Skim milk solids						
Other ingredients						
Utilities						
Electricity	Break drops		Short circuits		Hot wires	Shutdown
Gas	Break drops		Ignition of leaks		Leaks	Shutdown
Water	Break drops				Leaks	Shutdown
Fuel						
Process materials						
Grease			Grease fire			Cleanup
Supplies						
Office supplies						
Cleaning supplies						
Outputs						
Finished products						
Bread (loaf)						
Other bakery products						
Semiprocessed products						
Partly baked						
Products						
By-products						
Waste products						
Defective product						
Usual wastes						
People						
Employees	Wounds	Burns	Burns	Radiation sickness		Shelter, training exchangeable jobs
Bakers						
Deliverymen		(above notes apply to all people)				
Foremen						
Packers & wrappers						
Other operatives						
Mechanics						
Nonemployees						
FDA inspector						

Source: Stanford Research Institute

RECOVERY MANAGEMENT CONCEPTS AND RELATED MODEL DETAILS

Recovery Management Concepts

The information derived from applying the models to a range of attack situations and alternative countermeasure systems is needed to develop specific definitions of management functions and requirements. These functions and requirements are:[23] (1) situation assessment, (2) communications, (3) data processing, (4) specification of recovery requirements, (5) development of recovery plans and schedules, (6) decision guidance on plan selection, and (7) supervision and control of the recovery operations. The design features of the three civil defense organization models previously described include the consideration of these requirements and functions. Further, the models are so constructed that each functional representation corresponds to the actual operational functions of management. For example, in the research case, the situation assessment data would be supplied by other model computations, whereas in an operational case, the situation assessment data would be obtained from observation and status reports to the management organization.

The sequence of model application to describe postattack recovery starts with the situation assessment from the output of a damage assessment model, which provides computed indications of the status of survivors in terms of numbers and locations. The recovery requirements model uses these data in conjunction with machine-stored data on (1) all essential survival items and their expected consumption rates (physical units per day per survivor) and (2) stockpile-consumption relationships to make estimates of the times at which the production of essential items must be recovered. The recovery planning model also uses damage assessment data, which are combined with information (as a data base) on various countermeasures to generate alternative preattack preparation and postattack recovery plans. The outputs from both models are then used to select the feasible alternatives for implementation decisions by management.

The decision guidance information that can be derived from the recovery management model would be based on the results of feasibility analyses of the various recovery plans. The cost-effectiveness analyses would consider costs in terms of capital investments and maintenance for

the preattack preparations and in terms of other units of measure, such as manpower (number, skills, man-hours), equipment (amount, type, equipment-hours), materials (amount and type), and radiation dose (to both countermeasure and mission personnel) for the postattack recovery period.

The effectiveness of a postattack countermeasure system, while generally related to its capability for improving the environment or the feasibility of recovery, may be measured in physical performance units for specific countermeasures and in such terms as lives saved, reduction in radiation dose, reduction in recovery time, and increase in the rate at which the production of goods is recovered for a countermeasure system. It is conceivable that, for the possible range in postattack environments and recovery situations, combinations of the two will result in some cases where the recovery is cost-limited and effectiveness-limited. In other cases, the cost-effectiveness ratios may be used for direct comparison and selection of the best available set of countermeasures and consistent (and compatible) procedures for allocating available resources.

A recovery management model can be developed functionally from a range of outputs of the recovery planning model. Selection of a recovery plan, based on feasibility and cost-effectiveness, must meet the recovery requirements derived from the outputs of the requirements and planning models (in which the major constraints are the operational limitations of the countermeasures, the production rate of essential commodities needed to sustain survivors, and the capabilities of the survivors to recover and operate the facilities at the indicated levels). The scope and detail of the organizational structure required to implement the selected (or derived) plan can also be determined from the functional requirements of the recovery task.

Recovery Requirements Model Details

As the first step in developing the three models that will describe a civil defense organization, some of the equations for the internal computations of the recovery requirements model have been derived and applied to the food system. The following discussion focuses on the model functions that describe the basic relationships among consumption rates of essential survival commodities, stockpiles, production recovery times, and countermeasure scheduling.

The items essential for survival have been designated by the Office of Emergency Planning under seven major categories and are listed in Table 9. Systems that produce and distribute these items would be included in the model systems for deriving recovery requirements for the early postattack period. The list of survival items may show items that

Table 9

SURVIVAL ITEMS

1. Health supplies and equipment
   a. Pharmaceuticals
   b. Blood collecting and dispensing supplies
   c. Emergency surgical instruments and supplies
   d. Biologicals
   e. Surgical textiles
   f. Laboratory equipment and supplies
2. Food
   a. Milk group
   b. Meat and meat alternate group
   c. Vegetable-fruit group
   d. Grain products
   e. Fats and oils
   f. Sugars and syrups
   g. Food adjuncts
3. Body protection and household operations
   a. Clothing
   b. Personal hygiene items
   c. Household equipment
4. Electric power and fuels
   a. Electric power
   b. Petroleum products
   c. Gas
   d. Solid fuels
5. Sanitation and water supply
   a. Water
   b. Water supply materials
   c. Chemical, biological, and radiological (CBR) detection, protection, and decontamination items
   d. Insect and rodent control items
   e. General sanitation
6. Emergency housing and construction materials and equipment
7. General use items

Source: Reference 28

are not required for simple survival. It can be shortened if the capability to produce becomes limited after attack, or to emphasize certain types of items.

To indicate how the recovery requirements model parameters are related to those of the industrial models, some of the parameters and basic relationships for the industrial models are discussed in the following paragraphs. A summary of the parameter designators used in the discussion is given in Table 10.*

The average or instantaneous rate of change in any of the parameters is designated with a dot over the designator; thus dO_i/dt is represented by $\dot{O}_i$. For any defined industrial system, a finite number of parameters and relationships exist; thus, there are m survival items or commodities, n resources or materials, p processes or types of equipment, and r inputs other than people or materials. In general, it is convenient to number the processes in reverse order of occurrence (i.e., from last to first). According to the notation, each of several forms of a commodity (e.g., fresh milk, dried milk, skim milk, etc.) would be given a separate i number (or j number if it is an input to a process). The designations may be expanded for application to specific conditions; thus the output rate of commodity i from process k would be designated $\dot{O}_{ik}$.

$$\dot{O}_{ik} = a_{ijk} \dot{R}_{jk} \qquad (1)$$

$$\dot{O}_{ik} = b_{ik} N_k \qquad (2)$$

$$\dot{O}_{ik} = e_{ik\ell} \dot{I}_{\ell k} \qquad (3)$$

$$\dot{O}_{ik} = \epsilon_{ik} \dot{P}_k \qquad (4)$$

in which a_{ijk}, b_{ik}, $e_{ik\ell}$, and ϵ_{ik} are production coefficients for normal operating conditions of the system. For small variations in the parameters, the coefficients may be considered as constants. Since all four equations

* See Brown[13] and Billheimer[15] for comparison as to notation

TABLE 10

SUMMARY OF RECOVERY REQUIREMENT AND INDUSTRIAL MODEL PARAMETER DESIGNATORS

i	Commodity or survival item in the specific form in which it is consumed (e.g., fresh milk, dried milk, canned peas, gasoline, etc.)
j	Material resource input to a process: raw, semi-processed, or a consumer commodity i
k	Process or equipment required as one step in the production of commodity i
ℓ	Input other than a material resource or people
m	Arbitrarily selected number of commodities i
n	Number of resources or materials
p	Number of processes or types of equipment k involved in the production of commodity i
r	Number of inputs ℓ involved in the production of commodity i
O_i	Magnitude of the output of commodity i
R_j	Magnitude of the input of resource (material) j
P_k	Capacity level for process or equipment
N_k	Number of people associated with process k
I_ℓ	Magnitude of an input ℓ other than a material resource or people
C_i	Amount of commodity i that is consumed
c_i	Amount of commodity i consumed per person
N_i	Total number of people or consumers of commodity i
E_i	Inventory of the ith commodity at any time

Production coefficients relating four production limiting parameters to the production rate, $\dot{O}_i$, of commodity i:

a_{ijk}	for physical material inputs $\dot{R}_{jk}$
b_{ik}	for the number of people N_k
$c_{ik\ell}$	for inputs $\dot{I}_{\ell k}$ other than material or people
ϵ_{ik}	for the capacity level $\dot{P}_k$ of process or equipment k

Table 10 (concluded)

N_i^o	Number of overhead or non-operative persons associated with the production of commodity i
α_{ik}	Number of overhead persons per operating person for process k
$\beta_{\ell k}$	Excess of input I_ℓ per unit of input $I_{\ell k}$ normally associated with process k
O_i^*	Potential final output of commodity when all inventory in process is used
t_i	Consumption delay time (raw material to consumer)
t_{ik}	Production time for commodity i in process k
t_{id}	Distribution or delay time for commodity i
t_{is}	Storage time for commodity i
$\bar{t}_i$	Average consumption delay time
E_i^o	Inventory of commodity i at the start of the postattack period
τ_i	Time after start of the postattack period
T_i^o	Time after start of the postattack period when $E_i^o = 0$

Source: Stanford Research Institute

must be satisfied before a value of O_{ik} or $\dot{O}_{ik}$ is realized, the value of $\dot{R}_{jk}$, N_k, $\dot{I}_{\ell k}$, and $\dot{P}_k$ giving the lowest value of $\dot{O}_{ik}$ in reality establishes the maximum value $\dot{O}_{ik}$.

For a 40-hour week operation without breakdown, the value of ϵ_{ik}, by definition, would be 40/168 or 0.24; its average value might be less where occasional breakdowns occurred and repair time interrupted production. The maximum potential output for continuous operation would thus be controlled by Equation (4) with an ϵ_{ik} value of one. This equation could also control the maximum potential output under postattack conditions. If the facility equipment is destroyed, $\dot{P}_k$ is zero and $\dot{O}_{ik}$ is zero. If the equipment is damaged but is reparable, then the value of ϵ_{ik} is reduced (and may be zero until some degree of repair is achieved).

Under normal operating conditions, the number of people associated with the production of a commodity in one or more processes is larger than those associated with the processes; it is convenient to relate the number of these overhead persons, N_i^o, in proportion to the number of operating people so that:

$$N_i^o = \sum_{k=1}^{p} \alpha_{ik} N_k \qquad (5)$$

where α_{ik} is a proportionality constant for a given process. The total number of people for normal operation is then given by:

$$N_i = \sum_{k=1}^{p} (1 + \alpha_{ik}) N_k \qquad (6)$$

In postattack or other situations of manpower shortage, consideration can be given to decreasing the overhead staff to make better use of the facilities.

Also, in most operations, some of the utility inputs are larger than those required for production. Again, it is convenient to consider these excess inputs as fractional increases over the amounts required for productive needs. The total input requirement of ℓ is then given by:

$$\dot{I}_\ell = \sum_{k=1}^{p} (1 + \beta_{\ell k}) \dot{I}_{\ell k} \qquad (7)$$

in which $\beta_{\ell k}$ is a proportionality constant for a given process (and input).

In many production systems of more than one process, the output of one process becomes an input to a successive process; if the commodity i numbering system is in order of the processes, then $\dot{R}_{jk}$ for one process is equal to $\dot{O}_{(i + 1)(k + 1)}$ of the previous process (otherwise $i = i' + x$ and $k = k' + y$ where x and y are matrix translation numbers from one system to another).

The potential final output of commodity i at a given time from a series of processes where the output of one is an input to a succeeding process is given by:

$$O_i = \sum_{k=1}^{p} O_{ik} \tag{8}$$

$$O_i^* = \sum_{k=1}^{p} a_{ijk} R_{jk} \tag{9}$$

The inventory (stockpile) of the material or resource inputs at any time is defined by R_j or, if the same resource is used in more than one process, by:

$$R_j = \sum_{k=1}^{p} R_{jk} \tag{10}$$

The inventory (stockpile) of the commodity i (an input) at any time is defined by:

$$E_i = O_i - C_i \tag{11}$$

The above two inventory definitions were selected to facilitate accommodation to the recovery requirements model. The inventory of the resource j would indicate, through integration of Equation (1), the maximum potential output of commodity i if the other inputs are provided and the inventory is not replaced. The inventory for the commodity i probably could also be defined as O_i but since a time delay between production and consumption occurs, it is convenient to define the inventory as the amount available for consumption at a given time. In other words, the inventory

R_j would represent the stockpiles directly available for processing, whereas the inventory E_i would represent the stockpiles in the distribution chain or supply system between the points of production and consumption.

If the production times, t_{ik}, time of delivery (or transport), t_{id}, and the storage time, t_{is}, for a commodity are known, the product delivery lead time (or consumption delay time), t_i, can be estimated from:

$$t_i = \sum_{k=1}^{p} t_{ik} + t_{id} + t_{is} \tag{12}$$

In general, t_i would have a range of values mainly because of the possible variations in t_{id} and t_{is}. Maximum values of t_i would be expected to be limited by the storage life of perishable goods or by the marketing cycle of goods. Minimum values of t_i would be expected to be limited by the time required to transport the commodity to consumers with a minimum of storage time. An overall average value of t_i for the delivery lead time of the commodity i that is being produced and consumed at a constant rate ($\dot{E}_i = 0$) for an area may be estimated from:

$$\bar{t}_i = \frac{O_i + E_i}{\dot{C}_i} \tag{13}$$

Consumption and Stockpile Depletion Relationships

Per capita consumption rates for survival items can be determined in two ways: (1) by prorating the preattack annual production over the population and (2) by analyzing individual survivor requirements. The first is useful for investigating recovery potential on a national basis and testing whether items can be supplied at normal consumption rates as a desirable goal. The second would be used to evaluate recovery sequences at the minimum feasibility level of production.

If Equation (11) is evaluated at the end time of a nuclear war (or at the start of the postattack period) under the simplified condition that $\dot{O}_i$ is zero, then O_i in that equation is a constant, say E_i^o. Equation (11) can be rewritten as:

$$E_i = E_i^o - N_i \dot{c}_i \tau_i \tag{14}$$

in which $\dot{c}_i$ is assumed to be constant and τ_i is the time after attack. Another way of stating the rewrite of Equation (11) is that at τ_i equal

zero, the total consumption, C_i, is zero so that O_i at that time is equal to E_i (and designated E_i^o), the inventory of commodity i. The time T_i at which E_i becomes zero for a given number of consumers (i.e., survivors) may be represented by:

$$T_i^o = \frac{E_i^o}{N_i \dot{c}_i} \tag{15}$$

If the area considered is large enough, it should be expected that, for some commodities, the output from undamaged facilities could be realized from the stockpiles R_j. And, where this production took place such that $T_i^o \geq t_i$, then the potential consumption time would be represented by:

$$T_i^o = \frac{E_i^o + O_i}{N_i \dot{c}_i} \tag{16}$$

where

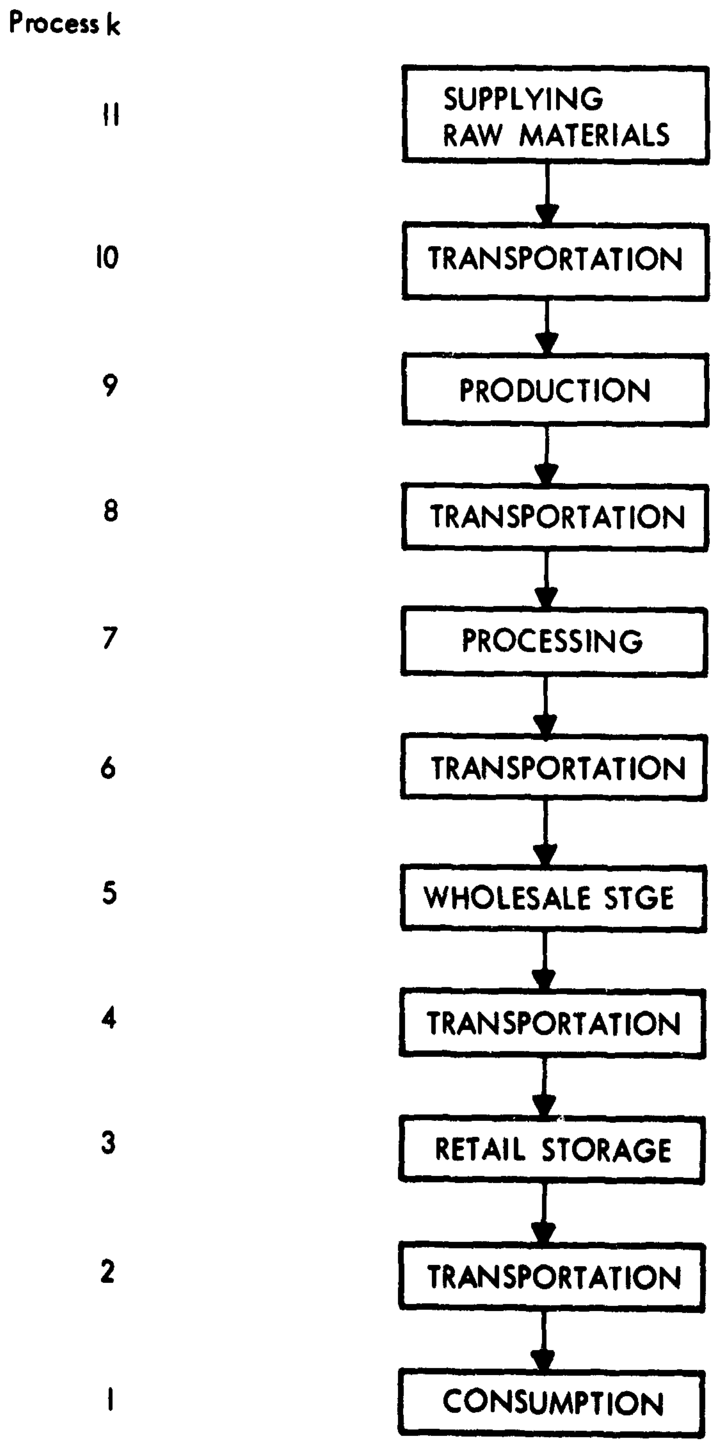
$$O_i = \sum_{k=1}^{p} a_{ijk} R_{jk} \tag{17}$$

The production system for a given survival item can be illustrated by a flow diagram that designates the steps or processes through which a raw material passes to the consumer. A generalized flow diagram that applies for many survival items from raw material to consumption is shown in Figure 14. Equations (16) and (17) represent the initial stages of the recovery process where the production from undamaged facilities is resumed even though at the initial stages the contribution from these facilities is considered only in terms of extending the potential consumption (or survival) time.

The value of T_i^o by Equation (16) is valid only if the entire inventory in the process chain can be depleted by consumption through supplying the inputs to the p processes. In recovery planning, where a number of survival items are competing for a supply-limited production input, the input may have to be allocated among the items (at least initially). This allocation may either eliminate some of the potential supplies from the earlier processing steps or decrease the amounts processed or both. Degradations in supplies and production capabilities resulting from weapon effects would be included in the estimate of the R_{jk} values. The recovery-degraded consumption-time is also represented by Equations (16) and (17), where p is the number of processes (starting with the last one in the chain) actually used. The value of R_{ik} may be less than for normal operations because the allocation of an input ℓ to the kth process is reduced. The value of R_{jk} is zero if the production capability of any process after the kth process (i.e., the process numbered k-1, counting from the last one in the chain) is zero. In other words, the output constraints set by Equation (1) through (4) still hold.

Figure 14

TYPICAL FLOW DIAGRAM FOR PRODUCT i THROUGH 11 PROCESSES



SOURCE: Stanford Research Institute.

Stockpile Use and Recovery

The full use of the stockpiles of all commodities, as indicated by Equations (16) and (17), would require the allocation of available inputs (some of which may also be commodities). In addition, the facilities for the indicated processing steps must be available. The recovery requirements model thus must include procedures for identifying the required facilities, the times when their production capability should be recovered, the time when the inputs should be recovered or made available, and a summary of the allocation requirements for the inputs.

The potential supply of commodity i, as represented by R_{jk} in Equation (17), can only be obtained by supplying resource inputs (man-hours, kwh, and so forth) to inventories in each process k in sufficient quantities to carry the product through p processes to the consumer. (At this point, the problem is one of recovery rather than only of survival.) The magnitude of the input ℓ required to complete the process k in the production of the commodity i is given by Equation (3). In the case of food, the coefficient $e_{ik\ell}$ will be physical units of the consumable edible product i in process k per unit of input ℓ.

The total input requirements for the full use of the inventory R_{ij} for m survival items distributed among p processes is:

$$I_\ell = \sum_{i=1}^{m} \sum_{k=1}^{p} \frac{a_{ijk}}{e_{ik\ell}} R_{jk} \tag{18}$$

In the case where the inventory for the input ℓ is less than I_ℓ from Equation (18), then, where a_{ijk}, $e_{ik\ell}$, and m are fixed, either p or R_{jk} (or both) must be reduced to conform to the available value of I_ℓ. Or, an additional capacity of I_ℓ must be recovered.

The rate at which the input ℓ must be supplied to maintain the commodity stockpiles from all processes and at the level O_{ij} is given by:

$$\dot{I}_\ell = \sum_{i=1}^{m} \sum_{k=1}^{p} \frac{a_{ijk}}{e_{ik\ell}} \dot{R}_{jk} \tag{19}$$

which is simply the differential of Equation (18) with respect to time.

In general, a given number of inputs are required in the k processes to produce each commodity. Thus, a matrix of I_ℓ or $\dot{I}_\ell$ parameters exists for each set of the k processes. And, for any combination or series of

processes and inputs where I_ℓ or $\dot{I}_\ell$ is zero, no product will be obtained from the kth process [as specified by Equation (3)]. Hence, if r inputs are needed, all must be supplied or the process cannot be carried out.

A three dimensional matrix for the production variables among inputs, products, and processes (designated as an inventory utilization matrix) is shown in Figure 15. As each form of the final product i across the front face moves vertically through processes k, inputs j and ℓ must be supplied at each process. The matrix can be expanded to include feedback loops and exchanges for cases where products are inputs to processes or where an input product could pass through process k with required inputs from itself.

In the early postattack period, the actual survival time on a national scale without recovery efforts is represented by Equation (15) or Equations (16) and (17) for k=1. In general, the readily available stockpiles of the survival items would probably be used to recover inputs for the final processing step (k=2) of the items, since this step should require the minimum expenditure of supplies and energy to increase the apparent stockpile. Further, the last step process would always be required before the product would be available to consumers. Thus, the recovery of the inputs and facilities should proceed over time in reverse order of the processing steps (i.e., in order of increasing k numbers). The priority in order of recovery could be established on the basis of the T_i^o values from Equation (15), the processing times (or lead times from the kth process), and the facility recovery time. The minimum input capacity of each kind for all survival items that needs to be recovered to sustain the N_i consumers is given by:

$$\dot{i}_\ell = \sum_{i=1}^{m} \sum_{k=1}^{p} \frac{N_i \dot{c}_i}{e_{ik\ell}} \tag{20}$$

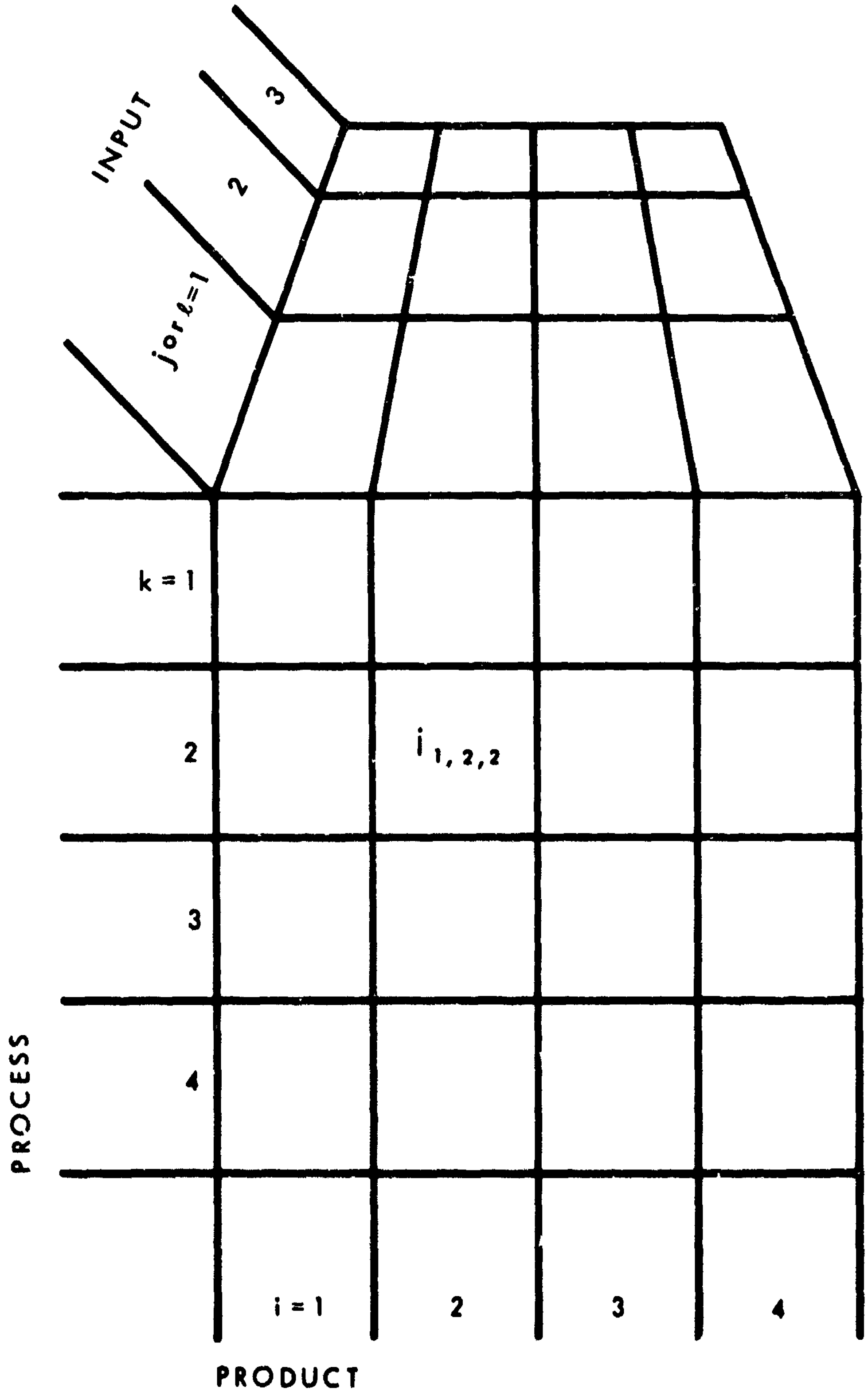
where Equation (20) represents the minimum equilibrium supply rate for each input in the k processes for all survival commodities that is consistent with the survival requirements defined by:

$$\dot{O}_i = N_i \dot{c}_i, \quad \tau_i \geq T_i^o \tag{21}$$

If the sums indicated by Equation (20) are evaluated in increasing order of the k values for each i and in the order of the i values according to the order of the T_i^o values from Equation (15), the order of recovery requirements of each input ℓ may be estimated. The accumulated sums would indicate the input needs during the initial stages of recovery for each

Figure 15

INVENTORY UTILIZATION MATRICES



SOURCE:
Stanford Research Institute.

commodity and process; for each increasing value of k (for a given commodity), the evaluation of Equation (20) should provide a stepwise requirement for the recovery of the input ℓ.

The minimum product delivery lead time for each successive step is given by Equation (12). When facility (or transport) recovery must be achieved to meet production and distribution needs, however, an additional delay may result from radiological recovery operations or repair of damaged facilities. These recovery needs will be evidenced by lack of inputs in resources, manpower, utilities, and facilities. If the maximum additional delay resulting from any cause other than processing, transport, and storage is designated as $\Delta t_{ik\ell}$, then the maximum recovery lead time for each successive stage in the recovery of the output from the k processes (because of lack of inputs) is given by:

$$T_i = t_i + \sum_{\ell=1}^{r} \sum_{k=1}^{p} \Delta t_{ik\ell} \tag{22}$$

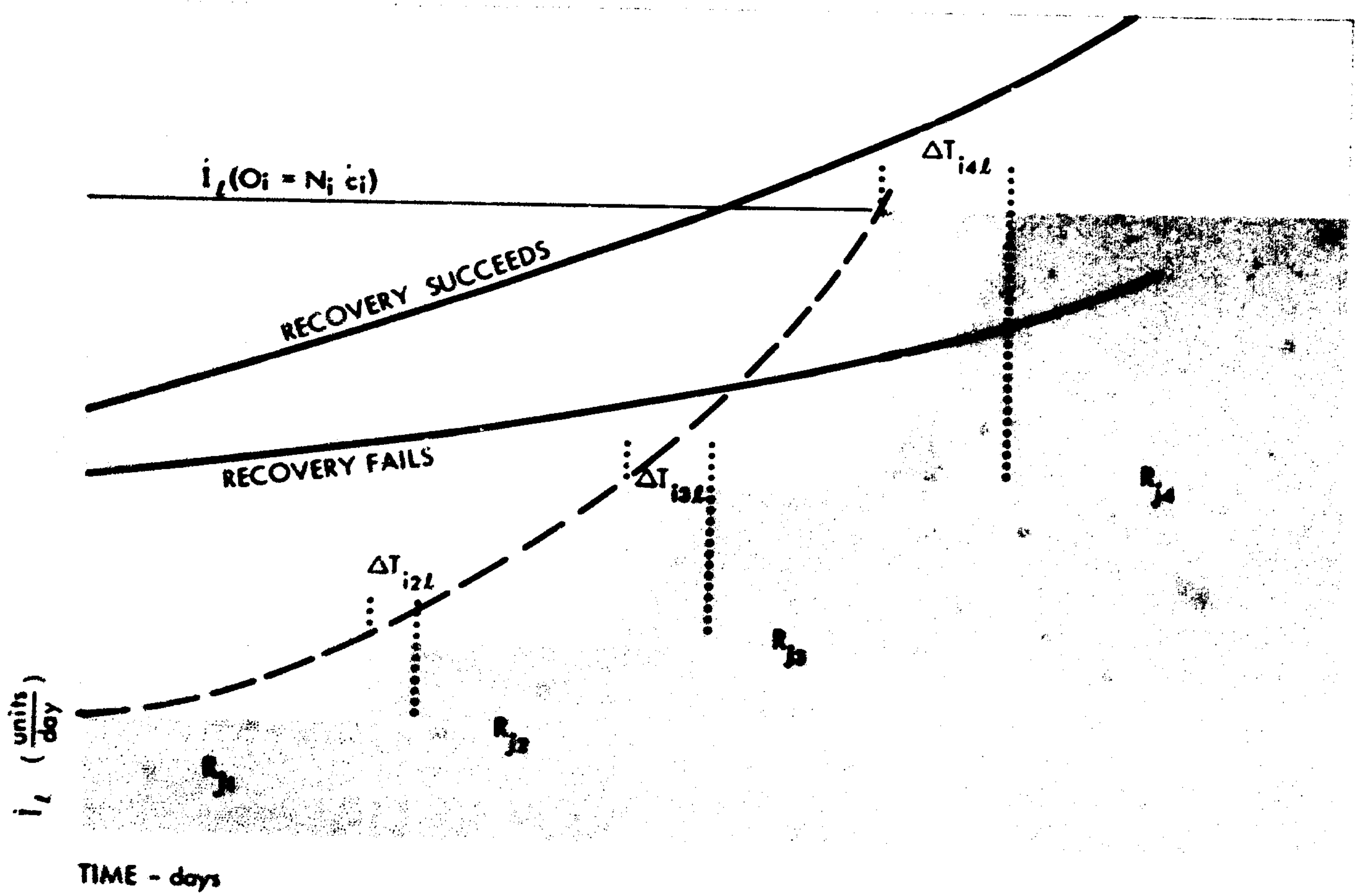
The double sum is given in Equation (22) to indicate a maximum delay time for the case in which the processes and inputs are recovered in sequence. This situation would probably not be a general case where several recovery countermeasures are carried out simultaneously by different groups of people. The real values of $\Delta t_{ik\ell}$ would be estimated from the recovery planning models; however, the minimum delay time requirements would be established by comparing estimates from Equation (15) or perhaps Equations (16) and (17) to determine feasible limits for the second term of Equation (22).

The results from Equations (20) and (12) or Equation (22) may be combined to establish a single product or commodity production requirement (or output) curve as a function of time. The true curve for a local area, as mentioned above, would be a step function reflecting discrete increases in inputs and outputs as the facilities are recovered and process inventories are brought into the production chain. On a national scale, the step functions would probably approach the form of a smooth curve.

The above concepts are illustrated in Figure 16 for a single input and product. The recovery of the supply rate of input ℓ is indicated by two arbitrarily drawn solid line curves; neither is conservative with respect to requirements. The third curve (broken line) is conservative with respect to the amount recovered and time of recovery. In the figure, the recovery rate curve that falls in the gray area represents failure after successful recovery of the output from three processes. It should

Figure 16

RELATIONSHIPS AMONG $\dot{I}_\ell$, SUPPLY AND DEMAND, INVENTORY R_{jk} IN PROCESS, AND RECOVERY CAPABILITY FOR PRODUCT i



SOURCE: Stanford Research Institute.

be noted that the recovery of the production from any number of successive processes and their inventories less than the total number of processes in the chain is equivalent to increasing the original stockpile and, if feasible, increases the survival time. On the other hand, the recovery of the production from all processes in the chain constitutes recovery of the industry to the degree required to sustain production at the survival level. This achievement would, in general, satisfy the first basic objective of a postattack recovery system.

Recovery Scheduling Techniques

As stated above, ultimate and sustained recovery will require the continuing operation of all related survival systems, including systems that provide raw materials. Therefore, it is important that recovery requirements of all systems, both individually and collectively, be projected as far as necessary into the postattack period for identifying problems of input shortages and for identifying countermeasures for solving these problems. Longer term problems such as these may require long lead times to resolve but, if anticipated, certain recovery variables could be altered. Alterations in variables that could lead to alternative recovery plans and procedures include: (1) revision of schedules for the supply of product i; (2) deletion, substitution, or reduction in consumption rate $\dot{c}_i$; (3) reduction in product quality; and (4) possible increase or substitution of inputs.

The steps for determining postattack recovery requirements and scheduling can be summarized as follows:

1. Determine the number of survivors (N_i).
2. Estimate a normal or minimum consumption rate, $\dot{c}_i$, for selected survival items, including acceptable substitute relationships among items.
3. Estimate the available and potentially consumable inventories, E_i and R_{ij}, of each survival item from preattack statistics and damage assessment summaries.
4. Estimate the potential consumption or survival times for each survival commodity--Equations (15) and (16).
5. Use the three-dimensional matrix (see Figure 15)--based on preattack economy data--the R_{ij} data, and damage assessment summaries of available inputs I_{ℓ} to estimate the total input capacities and production potentials required to maintain or regenerate the stockpile--Equations (18) and (19).
6. Estimate the requirements of input I_{ℓ} capacities for continued survival--Equation (7)--and compare these with results from Step 5.

7. Use Equations (8), (9), and (10) to develop a minimum requirement for the recovery of input I_ℓ (Figure 16) for r inputs and p processes to each of m survival items; cumulate the rate of input and estimate the allowed process delay times--Equation (20).
8. Sum the daily requirements for each input I_ℓ in Step 6 to obtain the total rate required as a function of time and repeat estimate of allowed delay times.
9. Compare the results of Steps 4, 6, and 7 to determine whether any input I_ℓ requirement exceeds availability at the minimum lead time, to enumerate bottleneck inputs, and to establish allocation priorities for the inputs.
10. If recovery is possible in Step 9 ($T_i(n)$ is greater than T_i), recovery scheduling and planning can proceed. Alternative recovery plans and schedules may be tested to evaluate those having the minimum delay times [these, by definition, should give the most rapidly rising curves for the variation of production (supply of R_i)] with time after attack.

Some of these steps are superficially applied to the food system in the appendix to indicate how available data can provide data bases for postattack recovery requirement and scheduling information.

SUMMARY AND RECOMMENDATIONS

A list of postattack recovery model systems was given under the four general categories of weapon effects and vulnerability, economic systems, countermeasures, and civil defense organization. A series of specific models in each general category was discussed briefly in terms of inputs, internal computational parameters, and outputs. The functional scope of each model as part of a recovery model system was described and the current state of development of each was indicated. A general approach to model design and development was given, using water and bread systems as detailed examples.

Some countermeasure models, which are a primary interest and responsibility of OCD, were outlined and discussed. Decontamination and dose control models, currently the most highly developed countermeasure models, were presented in the greatest detail. The inputs, internal computations, outputs, and parameter limits (from referenced associated research) were reasonably well defined. Other countermeasure models were diagrammed in terms of inputs, internal computation, and outputs, but computation procedures and parameter relationships and the ranges of applicable parameter values are yet to be defined.

Postattack management functions and requirements were discussed in parametric terms in model form for evaluating recovery requirements, recovery planning, and management operations. The theory of the recovery requirements model was developed in detail with a series of procedural steps for evaluating recovery requirements as a function of time. These steps, some of which were applied to the food system as an example, were based on concepts that should be applicable to essential survival items as well as to the recovery of the entire economy. However, the effort required to generate input data bases in the detail needed may limit initial application to selected essential survival items or to small regions.

The primary functions of the civil defense organization models for recovery requirements, planning and management are to develop feasible production recovery schedules from the recovery model system--and to develop recovery schedules that are designed to meet the needs of survivors. Except for the few recovery requirement model details developed as examples in this report, no quantitative methods are available for estimating postattack recovery requirements on a national scale.

Individual models of the recovery model system should be developed to the point where the model system can be tested. A rapid development of the system would require initial estimates of all major parameters and basic relationships. Later, these estimates could be replaced through more detailed research on each model. Testing the model system through sensitivity analyses could indicate where research effort to gain detailed information on each model should be concentrated. This approach is being used in continuing research on recovery model systems in the further development of models that can be applied to the study of organization and management requirements for a range of postattack situations.

REFERENCES

1. The Effects of Nuclear Weapons, Samuel Glasstone (ed.), U.S. Government Printing Office, Washington, D.C., April 1962

2. Miller, Carl F., Fallout Models and Radiological Countermeasure Evaluation, Stanford Research Institute Project MU-5116, May 1965

3. Miller, Carl F., Fallout and Radiological Countermeasures, Volumes I and II, Stanford Research Institute Project MU-4021, January 1963

4. Miller, Carl F., Contributions of Induced Radioactivities in Fallout from Nuclear Explosives (U), Report in preparation (SECRET - RD)

5. Miller, Carl F., Fallout Nuclide Solubility and Plant Part Uptake Contour Ratios, Stanford Research Institute Project MU-4021, July 1963

6. Miller, Carl F., and H. Lee, Operation Ceniza-Arena: The Retention of Fallout Particles from Volcán Irazu (Costa Rica) by Plants and People, Stanford Research Institute Project IMU-4890, January 1966

7. Miller, Carl F., and S. L. Brown, Models for Estimating the Absorbed Dose from Assimilation of Radionuclides in Body Organs of Humans, Stanford Research Institute Project IMU-4021, May 1963

8. Brown, Stephen L., Disintegration Rate Multipliers in Beta-Emitter Dose Calculations, Stanford Research Institute Project MU-5116, August 1965

9. Sartor, James D., W. B. Lane, and J. J. Allen, Uptake of Radionuclides by Plants, Stanford Research Institute Projects MU-5095 and MU-5893, December 1966

10. Air Force Design Manual, Principles and Practices for Design of Hardened Structures, AFSWC-TDR-62-138, December 1962

11. PARM System Manual, Agriculture and Food Processing, NREC Technical Report No. 54, June 1965

12. PARM System Manual, Manufacturing and Mining, NREC Technical Report No. 55, June 1965

13. Brown, Stephen L., Industrial Recovery Techniques, Stanford Research Institute Project MU-4949-350, April 1966

14. PARM System Manual, Noncommodity Activities, NREC Technical Report No. 56, June 1965

15. Billheimer, John W., and Harvey L. Dixon, Analysis of Postattack Food Processing and Distribution, Stanford Research Institute Project No. IMU-4021, June 1964

16. Miller, Carl F., H. Lee, and J. D. Sartor, Introduction to Radiological Defense Planning, Stanford Research Institute Project MU-5069, May 1965

17. Owen, W. L., F. K. Kawahara, and L. L. Wiltshire, Radiological Reclamation Performance Summary, Volume I, Performance Test Data Compilation, U.S. Naval Radiological Defense Laboratory, USNRDL-TR-746, August 1963

18. Rotz, J., J. E. Edmunds, and K. Kaplan, Formation of Debris from Buildings and Their Contents by Blast and Fire Effects of Nuclear Weapons, URS Corporation, Burlingame, California, URS651-4, April 1966

19. Fernald, O. H., et al., Critical Industry Repair Analysis, Food Industry, Advance Research, Inc., Needham Heights, Massachusetts, Report No. CIRA-3, Contract No. OCD-OS-62-251, April 1965

20. "Management of Mass Casualties," Symposium of Medical Field Service School, Brooke Army Medical Center, Fort Sam Houston, Texas, December 1961

21. Flanagan, R. J., et al., Vulnerability Reduction Using Movement and Shelter, Volume II, Dikewood Corporation, Albuquerque, New Mexico, DC-FR-1039, June 1965

22. Pettee, James C., The Emergency Stockpile Requirement for Processed Food, NREC Analysis Report No. 2, March 1964

23. Clark, D. E., Jr., C. F. Miller, and G. D. Hopkins, An Approach to Defining Postattack Recovery Management Concepts and Techniques, Stanford Research Institute Project MU-4536, November 1966

24. Miller, C. F., Outline of Research Program Content for Civil Defense, Office of Civil Defense, 1962

25. Billheimer, John W., Postattack Food Availability and Accessability - A Case Study, Stanford Research Institute Project MU-5516, December 1966

26. Description, Inventory, and Damage Assessment of Engineering Resources, OCD Contract PS-65-62, Emergency Operations Systems Development, Phase I Analytical Report-Engineering, Bradbury Associates, December 1965

27. Bakery Technology and Engineering, Samuel A. Matz (ed.), AVI Publishing Company, 1960

28. Guidance of Priority Use of Resources in Immediate Postattack Period, Defense Mobilization Order 8500.1A, Office of Emergency Planning, Federal Register, November 10, 1964 (29 FR 15R3)

Appendix

SOME RECOVERY REQUIREMENT MODEL PARAMETERS FOR THE FOOD SYSTEM

Appendix

SOME RECOVERY REQUIREMENT MODEL PARAMETERS FOR THE FOOD SYSTEM

Production and distribution of food in a postattack environment will play an important part in postattack survival and recovery. Because of its importance and the large number of detailed statistics available, the food chain of selected dietary items has been investigated as an example of the application of the theory and concepts discussed under "Recovery Management Concepts and Related Model Details."

Statistics on national production have been used to derive model parameter relationships to illustrate and describe the development of the recovery requirements model. Although application of data from national averages to local areas of different sizes can lead to misrepresentation, the application is suitable for demonstrating the types of input and output parameters required in the treatment and the internal data processing techniques that might be applied to local data bases.

General Supply, Consumption, and Diet Considerations

The agricultural products that are consumed as food are itemized by group under Item 2 of Table 9. Within each group are several products that, unprocessed or processed, are eaten in different forms, such as fresh, frozen, or canned. Data on normal eating habits and trends are summarized by U.S. Food Consumption[1] in terms of supply and consumption rates; the summaries include data on the annual per capita weight consumption of many foods according to the form in which they are retailed. These data were used to determine the specific foods that are most important in the national diet (on a consumption basis). A list of the food forms that are consumed in significant amounts and for which the recovery requirements model is applied in the example is given in Table A-1.

The normal daily consumption rate, $\dot{c}_i$, of the edible portion of each food form can be determined from per capita consumption data[1-4] or estimated from annual production figures[4-7] prorated over the contemporary population. This method evaluating $\dot{c}_i$ assumes that annual production and consumption are equal and that the consumption is spread evenly over the year.

Table A-1

SIGNIFICANT FOOD CONSUMPTION FORMS

Food	Fresh	Frozen	Canned	Dried	Cured	Juice	Processed
	Form						
Milk Group							
Whole Milk	x	x	x	x			
Cheese	x						
Cottage Cheese	x						
Meat and Meat Alternate Group							
Beef	x	x	x	x	x		
Pork	x	x	x	x	x		
Lamb, Mutton	x	x	x				
Chicken	x	x	x				
Turkey	x	x	x				
Eggs	x	x		x			
Fish	x	x	x	x			
Vegetable-Fruit Group							
Potatoes	x	x	x	x			
Tomatoes	x		x			x	x
Sweet Corn	x	x	x				
Snap Beans	x	x	x				
Field Beans			x	x			
Lima Beans	x	x	x				
Lettuce	x						
Cabbage	x		x				
Peas	x	x	x				
Onion				x			
Carrot	x	x	x				
Cantaloupe	x						
Watermelon	x						
Orange	x	x	x			x	
Grapefruit	x	x	x			x	
Peach	x	x	x	x			
Apple	x	x	x	x			
Almond	x						
Pecan	x						
Walnut	x						

Table A-1 (concluded)

Food	Form						
	Fresh	Frozen	Canned	Dried	Cured	Juice	Processed
Grain Products							
Wheat Flour							x
Wheat Cereal							x
Rye Flour							x
Rice	x						
Corn Meal							x
Corn Cereal							x
Corn Starch							x
Oats							x
Barley							x
Fats and Oils							
Lard							x
Butter							x
Margarine							x
Shortening							x
Edible Oils							x
Sugar and Syrups							
Cane Sugar							x
Beet Sugar							x
Corn Sugar							x
Food Adjuncts							
Coffee							x
Tea							x
Cocoa							x

Source: Reference 1 and Stanford Research Institute

If the inputs to the food production process (i.e., farming or ranching) are not considered, then the outputs (farm products) either go directly to consumers without change in form or ar inputs to a process where the form may be changed. Many of the farm products arrive at the consumer level in several forms. The fractional distribution of the farm output of a given commodity among several processes where it is an input in the preparation of another commodity (or another form of the original commodity) may be represented by:

$$\dot{R}_{jk} = f_{ijk}\,\dot{O}_{(i+x)(k+y)} \qquad \text{(A-1)}$$

in which f_{ijk} is the fraction of the farm output that becomes an input j to the kth process in the production of commodity i. The output of the commodity is then represented by:

$$\dot{O}_{ik} = f_{ijk}\,a_{ijk}\,\dot{O}_{(i+x)(k+y)} \qquad \text{(A-2)}$$

The value of the production coefficient, a_{ijk}, for any input-output combination depends on the units of measure of the two quantities. Thus, weight changes, partitioning of the input (more than one product can result in a given process), or combination with other inputs may result; but in general, a_{ijk} would be a pure number representing weight, volume, or number change.

Estimated values of $\dot{c}_i$, f_{ijk}, and a_{ijk} for significant food commodities are summarized in Table A-2 as obtained from data reported in Reference 3 to 11 (References 9 and 11 were particularly useful for this tabulation). In this table, $\dot{c}_i$ is a 1960 per capita retail food form consumption figure; f_{ijk} is the fraction of farm production (input j), which is allocated to processes k to produce food form i and is computed with the assumption that all of input j is accounted for in the food forms listed. The process dependent production coefficient a_{ijk} is the weight change factor that gives the number of pounds of farm production required to produce one pound of food form i at retail (k = o----n and a_{ijk} = 1.00 when k = o).

A check on the adequacy of the daily diet given by the sum of these $\dot{c}_i$ from Table A-2 shows that approximately 2,650 calories are provided when the food energy values derived by Merrill and Watt[12] are applied. Daily caloric requirements vary with individuals and the activities in which they are engaged--ranging from 50 calories per pound for infants to 4,500 calories for male adults doing heavy manual labor.

Several studies[13-16] have been made of the potential supply of food at various stages in the production and distribution system. The results of one of these studies[16] are summarized in Table A-3 on a national basis.

Table A-2

ESTIMATED VALUES OF $\dot{c}_i$, f_{ijk}, AND a_{ijk} FOR SIGNIFICANT FOOD COMMODITIES

Food Form i	$\dot{c}_i$ lb/day/Person at Retail	f_{ijk} Farm Production Fraction	a_{ijk} lb. Farm Production/lb. Retail
Milk			
Fresh	0.8823	0.465	1.00
Frozen	0.0501	0.040	1.50
Canned	0.0499	0.053	2.00
Dried	0.0200	0.084	8.00
Cheese	0.0227	0.065	7.14
Cottage Cheese	0.0129	0.038	5.56
Butter	0.0206	0.235	21.70
Beef			
Fresh	0.0672	0.507	1.93
Frozen	0.0112	0.084	1.93
Canned	0.0224	0.227	2.59
Dried	0.0056	0.091	4.14
Cured	0.0056	0.091	4.14
Pork			
Fresh	0.0407	0.212	1.60
Frozen	0.0068	0.035	1.60
Canned	0.0133	0.118	2.68
Dried	0.0034	0.047	4.29
Cured	0.0034	0.047	4.29
Pork (con'd)			
Lard	0.0208	0.541	8.00
Lamb			
Fresh	0.0048	0.684	2.43
Frozen	0.0006	0.088	2.43
Canned	0.0012	0.228	3.26
Chicken			
Fresh	0.0308	0.735	2.04
Frozen	0.0077	0.184	2.04
Canned	0.0024	0.081	2.88
Turkey			
Fresh	0.0081	0.467	2.00
Frozen	0.0081	0.467	2.00
Canned	0.0008	0.066	2.88
Eggs			
Fresh	0.0987	0.851	1.00
Frozen	0.0056	0.048	1.00
Dried	0.0027	0.101	4.33

Table A-2 (continued)

Food Form i	c_i lb/day/ Person at Retail	f_{ijk} Farm Production Fraction	a_{ijk} lb. Farm Production/ lb. Retail
Fish			
Fresh	0.0055	0.214	1.50
Frozen	0.0085	0.302	1.38
Canned	0.0110	0.402	1.42
Cured	0.0016	0.082	2.00
Potato			
Fresh	0.2487	0.756	1.00
Frozen	0.0059	0.018	1.00
Canned	0.0009	0.002	0.82
Dried	0.0133	0.224	5.57
Tomato			
Fresh	0.0311	0.222	1.00
Canned	0.0078	0.039	0.69
Juice	0.0132	0.145	1.54
Catsup	0.0104	0.181	2.44
Paste	0.0104	0.413	5.56
Sweet Corn			
Fresh	0.0080	0.261	1.00
Frozen	0.0017	0.150	2.69
Canned	0.0097	0.589	1.86

Food Form i	$\dot{c}_i$ lb/day/ Person at Retail	f_{ijk} Farm Production Fraction	a_{ijk} lb. Farm Production/ lb. Retail
Snap Beans			
Fresh	0.0063	0.484	1.00
Frozen	0.0019	0.154	1.06
Canned	[illegible]	0.362	0.68
Field Beans			
Canned	0.0192	0.277	0.34
Dried	0.0170	0.723	1.00
Lima Beans			
Fresh	0.0004	0.053	1.00
Frozen	0.0021	0.760	2.72
Canned	0.0008	0.187	1.79
Lettuce			
Fresh	0.0370	1.000	1.00
Cabbage			
Fresh	0.0216	0.840	1.00
Canned	0.0038	0.160	1.09

Table A-2 (continued)

Food Form i	$\dot{c}_i$ lb/day/ Person at Retail	f_{ijk} Farm Production Fraction	a_{ijk} lb. Farm Production/ lb. Retail
Peas			
Fresh	0.0002	0.008	1.00
Frozen	0.0045	0.450	2.37
Canned	0.0077	0.542	1.68
Onion			
Fresh	0.0295	1.000	1.00
Carrot			
Fresh	0.0114	0.826	1.00
Frozen	0.0009	0.080	1.24
Canned	0.0011	0.094	1.14
Cantaloupe			
Fresh	0.0140	1.000	1.00
Watermelon			
Fresh	0.0217	1.000	1.00
Orange			
Fresh	0.0344	0.089	1.00
Canned	0.0096	0.024	0.97
Frozen Juice	0.0413	0.856	8.00
Orange (con'd)			
Canned Juice	0.0059	0.031	2.00
Grapefruit			
Fresh	0.0122	0.280	1.00
Canned	0.0096	0.297	1.34
Frozen Juice	0.0021	0.386	8.00
Canned Juice	0.0007	0.037	2.27
Peach			
Fresh	0.0198	0.465	1.00
Frozen	0.0012	0.024	0.84
Canned	0.0180	0.365	0.86
Dried	0.0008	0.146	7.74
Apple			
Fresh	0.0419	0.604	1.00
Frozen	0.0022	0.029	0.89
Canned	0.0104	0.183	1.22
Dried	0.0016	0.184	8.00

Table A-2 (concluded)

Food Form i	$\dot{c}_i$ lb/day/ Person at Retail	f_{ijk} Farm Production Fraction	a_{ijk} lb. Farm Production/ lb. Retail	Food Form i	$\dot{c}_i$ lb/day/ Person at Retail	f_{ijk} Farm Production Fraction	a_{ijk} lb. Farm Production/ lb. Retail
Almond	0.0006	1.000	1.00	Margerine	0.0258	1.000	2.86
Pecan	0.0011	1.000	1.00	Shortening	0.0345	1.000	2.86
Walnut	0.0010	1.000	1.00	Oils	0.0315	1.000	2.86
Wheat				Cane Sugar	0.1943	1.000	10.00
Flour	0.3233	0.982	1.37	Beet Sugar	0.0767	1.000	7.14
Cereal	0.0074	0.018	1.08				
Rye Flour	0.0033	1.000	1.25	Coffee	0.0364	1.000	1.19
Rice	0.0167	1.000	1.50	Tea	0.0016	1.000	1.00
Corn				Cocoa	0.0079	1.000	1.25
Meal	0.0195	0.253	1.12				
Cereal	0.0049	0.149	2.63				
Starch	0.0049	0.090	1.59				
Syrup	0.0279	0.486	1.50				
Sugar	0.0101	0.022	1.85				
Oats	0.0096	1.000	1.67				
Barley	0.0027	1.000	1.41				

Table A-3

ESTIMATED FOOD SUPPLY AT
VARIOUS STAGES OF DISTRIBUTION
1963

	Days[a]	Cumulative Days
Home	9.0	9.0
Retail Food Stores	11.6	20.6
Wholesale Warehouses	11.7	32.3
Other[b]	52.3 $\pm$ 10.0	84.6 $\pm$ 10.0

a Based on 2650-calorie diet

b Includes unprocessed and surplus food stocks whose quantities fluctuate seasonally as well as from year to year

Source: Reference 16

In all of the studies, the supply was computed by dividing total calories of stored food by an assumed daily caloric requirement of the population. A balanced diet including specific food items was not considered.

A recovery requirements model must be able to account for each food product inventory in greater detail than the summation of available calories of all foods used to generate Table A-3. Each food form i is a separate system that must be understood in detail if the total system is to operate or is to be recovered in a postattack environment. A simplified approximation such as:

$$E_i^o = N_i \dot{c}_i T_i^o \qquad \text{(A-3)}$$

does not account for seasonal or regional variations in quantity of a specific food form i, particularly a fresh perishable food, even though the total caloric content of all foods stored in homes, retail, and wholesale locations remains about constant throughout the year. Unprocessed surplus food stocks have seasonal variations in both composition and quantity.

Equation A-3 is based on a consumption rate established by prorating the production of each food form uniformly over the time it is available. Adequate distribution is assumed, and each person has a daily (constant or seasonably variable) consumption rate $\dot{c}_i$ of each food form, whatever the size of the portion may be. Realistically, this apportionment of the food would be impractical and probably would not produce a balanced diet for individuals throughout the year because of the seasonal variation in supply. The Department of Agriculture has proposed national emergency food consumption standards that set forth food allowances per person per week, acceptable substitutes, and substitution rates for canned and concentrated foods.[17] Such standards can be used to apportion available foods among survivors at the local level to approximate balanced but not identical diets from available foods. These local variations of equivalent diets can be considered when the detail of the recovery requirements model is extended beyond the national level of the current example; further, the diets must be based on the stockpiles available at the time of an attack, so that some items will not be included if the attack occurs near harvest time. These detailed analyses will also indicate (1) how the consumption of various foods can be combined to follow the general guidance set forth by the USDA[17] and (2) whether that guidance is consistent with the feasibility of recovery of the food system.

Perishable Foods

Important factors in planning the most efficient consumption schedule for a perishable food crop are (1) harvest starting and completion dates

and period of maximum harvest activity or production rate, (2) delay time from production to consumption, (3) storage time without loss by spoilage, (4) total production of the crop, and (5) a spoilage factor. Simplified relationships among the first four factors in relation to harvest rate, consumption rate, and the stockpile size of a single perishable crop (with no processing steps) are shown in Figure A-1.

The output rates represented by Figure A-1a are:

$$\dot{O}_i = \frac{\dot{O}_i^m (t - t_o)}{(t_1 - t_o)} , \qquad t_o \le t \le t_1 \qquad \text{(A-4)}$$

$$\dot{O}_i = \dot{O}_i^m , \qquad t_1 \le t \le t_2 \qquad \text{(A-5)}$$

and

$$\dot{O}_i = \dot{O}_i^m \left[1 - \frac{(t - t_2)}{(t_3 - t_2)}\right] , \qquad t_2 \le t \le t_3 \qquad \text{(A-6)}$$

where t is the day of the year, t_o is the first day of harvest, t_1 is the first day of maximum harvest activity, t_2 is the last day of maximum harvest activity, t_3 is the last day of harvest, and $\dot{O}_i^m$ is the production rate during the period of maximum harvest activity.

The cumulative output (independent of the destination of the harvested crop) during the harvest period is represented by:

$$O_i(t) = \frac{\dot{O}_i^m (t - t_o)^2}{2(t_1 - t_o)} , \qquad t_o \le t \le t_1 \qquad \text{(A-7)}$$

$$O_i(t) = \dot{O}_i^m \left[t - \frac{(t_o + t_1)}{2}\right] , \qquad t_1 \le t \le t_2 \qquad \text{(A-8)}$$

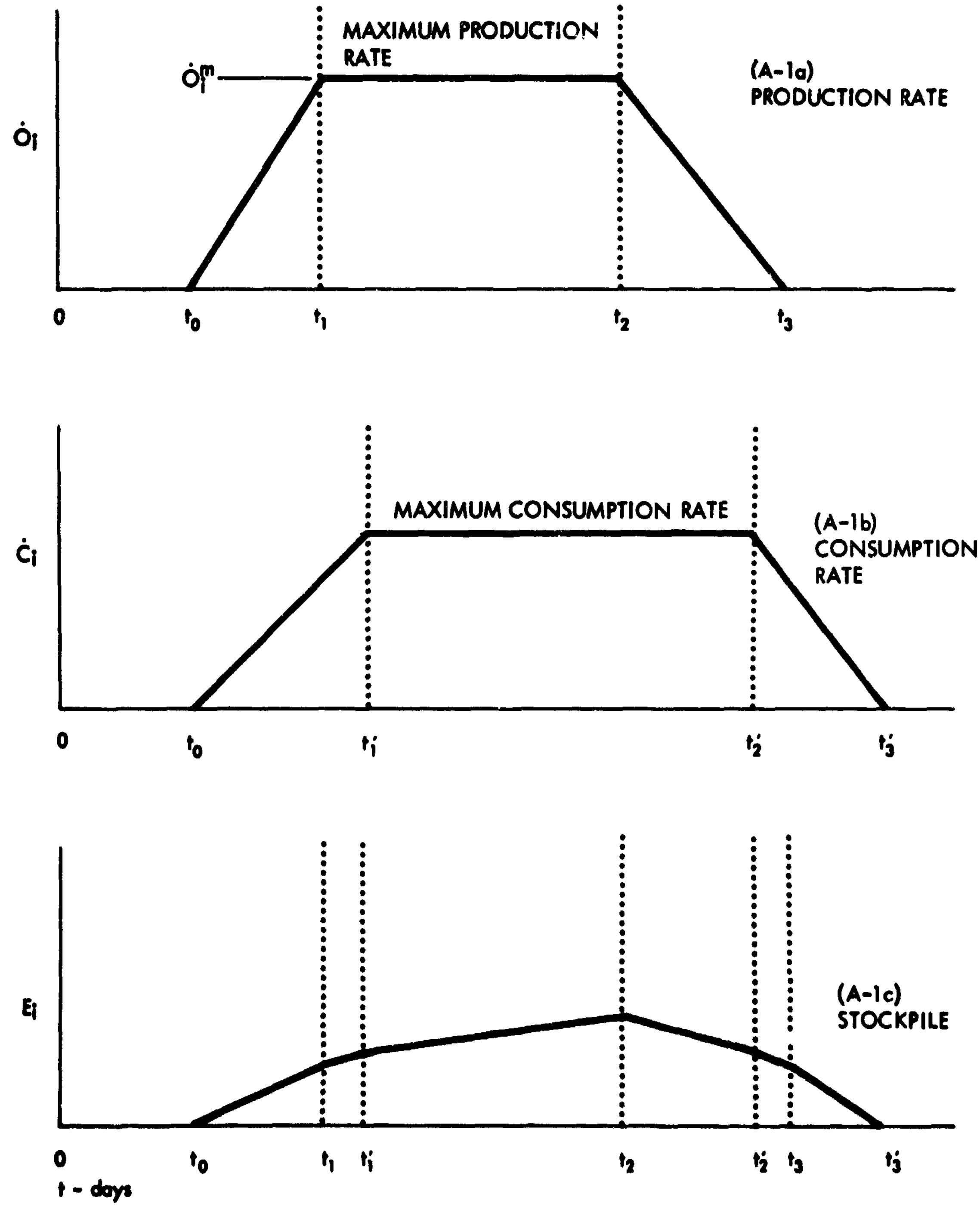
and

$$O_i(t) = \frac{\dot{O}_i^m}{2} \left\{ (t - t_2) \left[1 - \frac{(t - t_2)}{(t_3 - t_2)}\right] + 2t_2 - t_o - t_1 \right\},$$

$$t_2 \le t \le t_3 \qquad \text{(A-9)}$$

Figure A -1

RELATIONSHIPS AMONG PRODUCTION RATE, CONSUMPTION RATE, AND THE STOCKPILE OF A SINGLE PERISHABLE CROP



SOURCE: Stanford Research Institute.

The total production is obtained by setting t equal to t_3 in Equation (A-9); it is given by:

$$O_i(t_3) = \frac{\dot{O}_i^m}{2}(t_2 + t_3 - t_o - t_1) \qquad \text{(A-10)}$$

Generally, consumption begins at the same time as the harvest for areas adjacent to the production sites. However, the consumption rate over the country (or a large area) will not reach a plateau until sometime after the production rate becomes constant and output is delivered to the farthest market. The same time delay in the maximum consumption rate would be expected after the harvest rate begins to decline. And finally, the consumption rate must vanish at a time after production stops, determined by the maximum storage time before spoilage occurs. The above assumptions and the consumption-rate pattern given by Figure A-1b are represented by:

$$\dot{C}_i = \frac{\dot{C}_i^m (t - t_o)}{(t_1' - t_o)}, \qquad t_o \le t \le t_1' \qquad \text{(A-11)}$$

$$\dot{C}_i = \dot{C}_i^m, \qquad t_1' \le t \le t_2' \qquad \text{(A-12)}$$

$$\dot{C}_i = \dot{C}_i^m \left[1 - \frac{(t - t_2')}{(t_3' - t_2')}\right], \qquad t_2' \le t \le t_3' \qquad \text{(A-13)}$$

where t_1' is the first day of maximum consumption rate, t_2' is the last day of maximum consumption rate, t_3' is the last day of consumption, and $\dot{C}_i^m$ is the maximum consumption rate.

The cumulative amounts of the crop consumed are given by:

$$C_i(t) = \frac{\dot{C}_i^m (t - t_o)^2}{2(t_1' - t_o)}, \qquad t_o \le t \le t_1' \qquad \text{(A-14)}$$

$$C_i(t) = \dot{C}_i^m \left[t - \frac{(t_o + t_1')}{2}\right], \qquad t_1' \le t \le t_2' \qquad \text{(A-15)}$$

and

$$C_i(t) = \frac{\dot{C}_i^m}{2}\left\{(t - t_2')\left[1 - \frac{(t - t_2')}{(t_3' - t_2')}\right] + 2t_2' - t_o - t_1'\right\},$$

$$t_2' \le t \le t_3' \qquad \text{(A-16)}$$

According to the above discussion, the time delays for delivery and storage (or spoilage) result in the following relationships among the time parameters:

$$t_1' = t_{id} + t_1 \qquad \text{(A-17)}$$

$$t_2' = t_{id} + t_2 \qquad \text{(A-18)}$$

and

$$t_3' = t_{is} + t_3 \qquad \text{(A-19)}$$

where t_{id} is the maximum delivery time (for delivery to farthest significant consumer group) and t_{is} is the maximum storage time (i.e., storage time at which spoilage occurs). Thus, for a perishable commodity, t_{id} must always be less than t_{is} for full utilization of the output. Substitution of Equations (A-17), (A-18), and (A-19) for Equation (A-16) and evaluation at t_3' gives:

$$C_i(t_3') = \frac{\dot{C}_i^m}{2}\,(t_2 + t_3 + t_{is} - t_o - t_1) \qquad \text{(A-20)}$$

If f_{ijk} is the fraction of the harvested crop that is utilized in perishable form, then $C_i(t_3')$ is equal to $f_{ijk}\,O_i(t_3)$ and, from Equations (A-10) and (A-20), the production and consumption parameters are related by:

$$\dot{O}_i^m = \frac{\dot{C}_i^m\,(t_2 + t_3 + t_{is} - t_o - t_1)}{f_{ijk}(t_2 + t_3 - t_o - t_1)} \qquad \text{(A-21)}$$

If $\dot{c}_i$ is evaluated in terms of the average daily consumption of the commodity over a year's time, then the output required to supply N_i people is given by:

$$O_i(t_3) = \frac{365\,N_i\,\dot{c}_i}{f_{ijk}} \qquad \text{(A-22)}$$

The inventory at any time between t_o and t_3' is given by:

$$E_i(t) = O_i(t) - C_i(t) \qquad \text{(A-23)}$$

where $O_i(t)$ for t greater than t_3 is equal to $O_i(t_3)$.

If more than one cropping or harvesting of the same commodity occurs in one year, then the output $O_i(t)$ and consumption $C_i(t)$ are redesignated as $O_{ix}(t)$ and $C_{ix}(t)$, respectively, for each of the harvests. The total output for the yearly harvest is then given by:

$$O_i(t) = \sum_{x=1}^{z} O_{ix}(t) \qquad \text{(A-24)}$$

where z is the total number of croppings. The total amount consumed is given by:

$$C_i(t) = \sum_{x=1}^{z} C_{ix}(t) \qquad \text{(A-25)}$$

In the case of several croppings, the equality stated by Equation (A-21) is not required; however, if it holds for each cropping, then the yearly crop is consumed. The requirement stated by Equation (A-21) becomes:

$$O_i(365) = \frac{365\ N_i\ \dot{c}_i}{f_{ijk}} \qquad \text{(A-26)}$$

The production and consumption characteristics must be computed separately for each cropping to ensure that the inventories are not mixed and that t_{id} is less than t_{ie} for each harvest. Thus, several croppings can contribute to the stockpile only if the difference in their respective values of t_o is less than t_{is}.

As an example of concurrent consumption of several croppings of a fresh perishable food, lima bean consumption is analyzed on a national basis. The pertinent factors of Equations (A-4) through (A-21) are given in Table A-4, together with the computed values for $\hat{O}_i^m$ and $\hat{C}_i^m$ illustrated in Figure 1. The seasonal variation of the concurrent consumption of fresh lima beans, on a national basis, where the number of crops contributing to consumption varies from none to nine, grown throughout the year,

Table A-4

$\dot{O}_1^m$ AND $\dot{C}_1^m$ FOR FRESH LIMA BEAN CROPS

Time	State	Crop x	t_0 [a] day	t_1 [a] day	t_2 [a] day	t_3 [a] day	t_1' [b] day	t_2' [c] day	t_3' [d] day	$O_{1x}(t_3)$ 10^3 cwt	$\dot{O}_{1x}^m$ cwt/day	$\dot{C}_{1x}^m$ cwt/day
Winter	Fla.	1	-16	1	90	90	4	93	102	6	62	58
Spring	S.C.	2	140	166	196	212	169	199	224	42	824	737
	Fla.	3	91	91	151	166	94	154	178	42	622	571
Summer	N.Y.	4	213	213	273	304	216	276	316	26	344	319
	N.J.	5	191	196	243	304	199	246	316	61	763	709
	Md.	6	182	182	243	273	185	246	285	20	263	244
	N.C.	7	161	161	212	222	164	215	234	50	893	806
	Ga.	8	140	152	243	304	155	246	316	122	957	914
	Ala.	9	140	152	243	304	155	246	316	80	627	599

NOTES:

a Reference 19, page 2

b Assumed $t_1 + 3$ days ($t_{1d}=3$)

c Assumed $t_2 + 3$ days ($t_{1d}=3$)

d t_3+12 days (t_{1s}=12) Reference 18, page 18-02

e Reference 4, Table 312, 1960

is given in Table A-5. Intermediate values of $\dot{C}_i$ can be obtained by straight-line interpolation.

Nonperishable Foods

Food forms that can be stored until the start of the next harvest period have a seasonal variation of their stockpile E_i as shown in Figure A-2. Unlike fresh perishable crops, all crops can contribute concurrently to the consumption rate throughout the year so that the rate is:

$$\dot{C}_i = N_i \dot{c}_i \tag{A-27}$$

and the total consumption up to any time is:

$$C_i(t) = N_i \dot{c}_i t \quad , \quad 0 \le t \le 365 \tag{A-28}$$

The total consumption for the year is then 365 $N_i \dot{c}_i$. If only one cropping occurs, production or harvest parameters for minimum production requirements are specified by:

$$\dot{O}_i^m = \frac{730 N_i \dot{c}_i}{(t_2 + t_3 - t_o - t_1)} \tag{A-29}$$

For the case where more than one cropping occurs, the minimum production requirement is given by:

$$O_i = \sum_{x=1}^{z} O_{ix} = \frac{365 N_i \dot{c}_i}{f_{ijk}} \tag{A-30}$$

The above requirements, as derived on the basis of the $\dot{c}_i$ values for each crop, may be adjusted (as mentioned previously) to some degree on the basis of total dietary needs and substitutions of one food for another (although the sums over the i products are not indicated here). Over any period of time, the costs associated with the output production at the level $\dot{O}_i^m$ may be the controlling factor in the selection of the diet items and the crops to be grown in a postattack environment. The above equations indicate only how the production outputs can be related to diet requirements, to their delivery times, and to the food stockpile.

Table A-5

SEASONAL VARIATION OF FRESH LIMA BEAN CONSUMPTION

t	Crop x[a]									$\dot{C}_i$ [b]
day	1	2	3	4	5	6	7	8	9	cwt/day
0	X									46
4	X									58
91	X		X							58
93	X		X							439
94	X		X							629
102			X							571
140		X	X					X	X	571
154		X	X					X	X	2339
155		X	X					X	X	2441
161		X	X				X	X	X	2451
164		X	X				X	X	X	3262
169		X	X				X	X	X	3270
178		X					X	X	X	3056
182		X				X	X	X	X	3056
185		X				X	X	X	X	3300
191		X			X	X	X	X	X	3300
199		X			X	X	X	X	X	4009
213		X		X	X	X	X	X	X	3596
215		X		X	X	X	X	X	X	3750
216		X		X	X	X	X	X	X	3785
224				X	X	X	X	X	X	3209
234				X	X	X		X	X	2785
246				X	X	X		X	X	2785
276				X	X	X		X	X	1644
285				X	X			X	X	1231
316										0
349	X									0
365	X									46

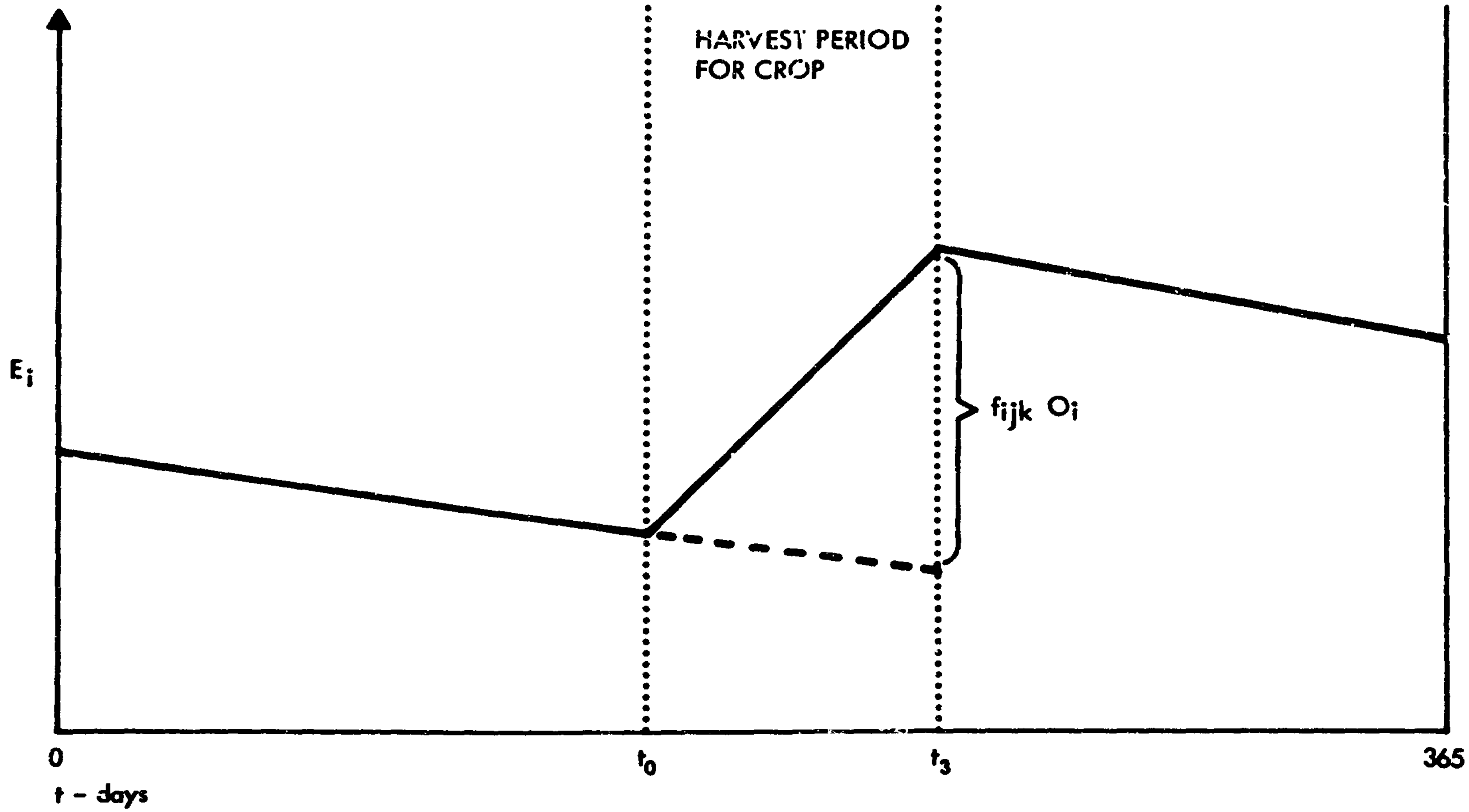
a See Table A-4

b National consumption of concurrent crops

Source: Stanford Research Institute

Figure A - 2

SEASONAL VARIATION OF E_i FOR NONPERISHABLE FOOD PRODUCT i



SOURCE: Stanford Research Institute.

PRECEDING
PAGE BLANK

APPENDIX REFERENCES

1. U.S. Food Consumption, Sources of Data and Trends, 1909-63, Statistical Bulletin No. 364, U.S. Department of Agriculture, Economic Research Service, Washington, D.C., June 1965

2. Statistical Abstract of the United States: 1966 (87th edition), U.S. Bureau of the Census, Washington, D.C., 1966

3. Food Consumption per Person in Households in the United States, 1955, U.S. Department of Agriculture, Agriculture Research Service, HHE (ADM)-200, May 1960

4. Agricultural Statistics 1962, U.S. Department of Agriculture, Washington, D.C., 1963

5. 1958 Census of Manufactures, Volume I, Summary Statistics, U.S. Department of Commerce, Washington, D.C., 1960

6. Frozen Food Fact Book and Directory, 1960-61, National Frozen Food Association, New York

7. The Almanac of the Canning, Freezing, Preserving Industries, Edward E. Judge (ed.), Westiminster, Maryland, July 1966

8. The Canned Food Reference Manual, Third Edition, American Can Company, New York, 1949

9. Food Yields: Summarized by Different Stages of Preparation, Agriculture Handbook No. 102, U.S. Department of Agriculture, Washington, D.C., June 1956

10. Volume-Weight Conversion Factors for Milk, Supplement to Marketing Research Report No. 701, U.S. Department of Agriculture, Consumer and Marketing Service, Washington, D.C., June 1965

11. Conversion factors and Weights and Measures for Agricultural Commodities and Their Products, Statistical Bulletin No. 362, U.S. Department of Agriculture, Economic Research Service, Washington, D.C., June 1965

12. Energy Value of Foods: Basis and Derivation, Agriculture Handbook No. 74, U.S. Department of Agriculture, Washington, D.C., March 1955

13. Number of Days' Supply of Food and Beverages in Retail Food Stores, Marketing Research Report No. 286, U.S. Department of Agriculture, Agricultural Marketing Service, Washington, D.C., November 1958

14. Estimated Number of Days' Supply of Food and Beverages in Retail Stores, 1962, Marketing Research Report No. 577, U.S. Department of Agriculture, Economic Research Service, Washington, D.C., December 1962

15. Estimated Number of Days' Supply of Food and Beverages in Warehouses at Wholesale, 1963, Marketing Research Report No. 632, U.S. Department of Agriculture, Economic Research Service, Washington, D.C., 1963

16. Food Supplies Available by Counties in Case of a National Emergency, Agricultural Economic Report No. 57, U.S. Department of Agriculture, Economic Research Service, Washington, D.C., July 1964

17. Emergency Feeding-Emergency Welfare Service Manual, U.S. Department of Health, Education, and Welfare, Bureau of Family Services and the Childrens Bureau, Washington, D.C., 1963

18. Air Conditioning Refrigerating Data Book, Applications Volume, Fifth Edition, American Society of Refrigeration Engineers, 1955

19. Commercial Vegetables for Fresh Market: Usual Planting Dates, Usual Harvesting Dates, Principal Producing Areas, by Season Groups and States, Agricultural Handbook No. 80, U.S. Department of Agriculture, Agricultural Marketing Service, Washington, D.C., December 1954

UNCLASSIFIED

Security Classification

DOCUMENT CONTROL DATA - R&D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author) STANFORD RESEARCH INSTITUTE Menlo Park, California	2a. REPORT SECURITY CLASSIFICATION UNCLASSIFIED 2b. GROUP

3. REPORT TITLE

POSTATTACK RECOVERY MANAGEMENT:
CONCEPTS AND TECHNIQUES FOR MODEL DEVELOPMENT

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)

5. AUTHOR(S) (Last name, first name, initial)

CLARK, Donald E., Jr.
MILLER, Carl F.

6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
March 1967	93	47

8a. CONTRACT OR GRANT NO. OCD-PS-66-11 b. PROJECT NO. OCD Work Unit No. 3531A c. SRI Project No. MU-5710 d.	9a. ORIGINATOR'S REPORT NUMBER(S) 9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)

10. AVAILABILITY/LIMITATION NOTICES

Distribution of this document is unlimited.

11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY Office of Civil Defense Department of the Army Washington, D.C. 20310

13. ABSTRACT

A postattack recovery model system is described under the four general categories of weapon effects and vulnerability, economic systems, countermeasures, and civil defense organization. Specific models in each category are listed, discussed briefly in terms of inputs, internal computational parameters, and outputs. References are given that describe the current state of development for each model. A general approach to model design and development is given, including water and bread systems as detailed examples. The application of models to develop a civil defense organization to manage postattack recovery operations is described.

DD FORM 1 JAN 64 1473

UNCLASSIFIED

Security Classification

UNCLASSIFIED

Security Classification

14 KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Civil defense						
Postattack recovery management						
Postattack recovery models						
Postattack countermeasure models						
Debris clearance						
Damage repair						
Decontamination						

INSTRUCTIONS

1. ORIGINATING ACTIVITY: Enter the name and address of the contractor, subcontractor, grantee, Department of Defense activity or other organization *(corporate author)* issuing the report.

2a. REPORT SECURITY CLASSIFICATION: Enter the overall security classification of the report. Indicate whether "Restricted Data" is included. Marking is to be in accordance with appropriate security regulations.

2b. GROUP: Automatic downgrading is specified in DoD Directive 5200.10 and Armed Forces Industrial Manual. Enter the group number. Also, when applicable, show that optional markings have been used for Group 3 and Group 4 as authorized.

3. REPORT TITLE: Enter the complete report title in all capital letters. Titles in all cases should be unclassified. If a meaningful title cannot be selected without classification, show title classification in all capitals in parenthesis immediately following the title.

4. DESCRIPTIVE NOTES: If appropriate, enter the type of report, e.g., interim, progress, summary, annual, or final. Give the inclusive dates when a specific reporting period is covered.

5. AUTHOR(S): Enter the name(s) of author(s) as shown on or in the report. Enter last name, first name, middle initial. If military, show rank and branch of service. The name of the principal author is an absolute minimum requirement.

6. REPORT DATE: Enter the date of the report as day, month, year, or month, year. If more than one date appears on the report, use date of publication.

7a. TOTAL NUMBER OF PAGES: The total page count should follow normal pagination procedures, i.e., enter the number of pages containing information.

7b. NUMBER OF REFERENCES: Enter the total number of references cited in the report.

8a. CONTRACT OR GRANT NUMBER: If appropriate, enter the applicable number of the contract or grant under which the report was written.

8b, 8c, & 8d. PROJECT NUMBER: Enter the appropriate military department identification, such as project number, subproject number, system numbers, task number, etc.

9a. ORIGINATOR'S REPORT NUMBER(S): Enter the official report number by which the document will be identified and controlled by the originating activity. This number must be unique to this report.

9b. OTHER REPORT NUMBER(S): If the report has been assigned any other report numbers *(either by the originator or by the sponsor)*, also enter this number(s).

10. AVAILABILITY/LIMITATION NOTICES: Enter any limitations on further dissemination of the report, other than those imposed by security classification, using standard statements such as:

(1) "Qualified requesters may obtain copies of this report from DDC."

(2) "Foreign announcement and dissemination of this report by DDC is not authorized."

(3) "U. S. Government agencies may obtain copies of this report directly from DDC. Other qualified DDC users shall request through ______________."

(4) "U. S. military agencies may obtain copies of this report directly from DDC. Other qualified users shall request through ______________."

(5) "All distribution of this report is controlled. Qualified DDC users shall request through ______________."

If the report has been furnished to the Office of Technical Services, Department of Commerce, for sale to the public, indicate this fact and enter the price, if known.

11. SUPPLEMENTARY NOTES: Use for additional explanatory notes.

12. SPONSORING MILITARY ACTIVITY: Enter the name of the departmental project office or laboratory sponsoring *(paying for)* the research and development. Include address.

13. ABSTRACT: Enter an abstract giving a brief and factual summary of the document indicative of the report, even though it may also appear elsewhere in the body of the technical report. If additional space is required, a continuation sheet shall be attached.

It is highly desirable that the abstract of classified reports be unclassified. Each paragraph of the abstract shall end with an indication of the military security classification of the information in the paragraph, represented as *(TS)*, *(S)*, *(C)*, or *(U)*.

There is no limitation on the length of the abstract. However, the suggested length is from 150 to 225 words.

14. KEY WORDS: Key words are technically meaningful terms or short phrases that characterize a report and may be used as index entries for cataloging the report. Key words must be selected so that no security classification is required. Identifiers, such as equipment model designation, trade name, military project code name, geographic location, may be used as key words but will be followed by an indication of technical context. The assignment of links, roles, and weights is optional.